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# CPT CHARACTERIZATION WITH FUEL FLUORESCENCE (FFD) AND WATER SAMPLE COLLECTION

**Naval Weapons Station (NWS) Earle**
**Colts Neck, New Jersey**

APPLIED RESEARCH ASSOCIATES, INC.
*Engineering and Applied Science*

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**Naval Weapons Station (NWS) Earle**
**Colts Neck, New Jersey**

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# SECTION 1

# CPT CHARACTERIZATION WITH FUEL FLUORESCENCE (FFD) AND WATER SAMPLE COLLECTION
## Naval Weapons Station (NWS) Earle

## INTRODUCTION

Applied Research Associates, Inc. (ARA), under contract to Brown & Root Environmental, conducted Piezo-Electric Cone Penetration and Fuel Fluorescence Detector Tests (P-CPT) in support of the geotechnical site investigation at the site of the Naval Weapons Station (NWS) Earle. The purpose of this field effort was to investigate the underlying soils to determine site stratigraphy, in support of the Brown & Root Environmental study. This report documents ARA's site investigation efforts, test techniques and analysis of the data for field work conducted from 9 October 1996 to 28 October 1996. Presented are the field testing methods, data analysis techniques, and plots of the data gathered.

## TEST LOCATIONS

Thirty-nine cone penetration tests have been conducted as a part of the investigation as specified by the Brown & Root Environmental site representative. Thirty-one of these tests included the Fuel Fluorescence Detector (FFD) in addition to the standard P-CPT. The test identification, type of test, location, date, and depth of penetration are listed in Table 1.1.

## GROUND WATER SAMPLES

Thirty-one ground water samples were collected at site 26 using the CPT truck. These samples were taken at three potential depth intervals. These intervals were 20, 40, and 60 feet,

but varied due to site specific conditions. All depths, and sample collection locations were under the direction of the Brown and Root site representative. The actual sample depths are listed in Table 1.2. The samples were handed over to the custody of the Brown & Root site representative.

## REPORT OUTLINE

This report is organized into five sections and one Appendix. Section 2 discusses the P-CPT equipment and field procedures. Section 3 contains a discussion of techniques for estimating soil properties. A summary of typical data from the site is located in Section 4. Section 5 is the List of References.

Plots of the CPT data are presented in Appendix A for all locations. Plots of CPT data include tip resistance (psi), sleeve friction (psi), friction ratio, pore pressure (psi), soil classification, and FFD Output (Vdc).

**Table 1.1 Summary of Tests at Naval Weapons Station (NWS) Earle**

| Test Id. | Type of Test | Date of Test | Max Depth of Penetration (ft) | Depth to GWT (ft) |
|---|---|---|---|---|
| 16CPT-01 | FFD/P-CPT | 10/9/96 | 15.1 | 8.8 |
| 16CPT-02 | FFD/P-CPT | 10/9/96 | 15.1 | 9.0 |
| 16CPT-03 | FFD/P-CPT | 10/9/96 | 18.0 | 6.0 |
| 16CPT-04 | FFD/P-CPT | 10/9/96 | 14.7 | 7.8 |
| 16CPT-05 | FFD/P-CPT | 10/9/96 | 14.9 | 8.2 |
| 16CPT-06 | FFD/P-CPT | 10/9/96 | 14.9 | 7.4 |
| 16CPT-07 | FFD/P-CPT | 10/9/96 | 15.0 | 7.6 |
| 16CPT-08 | FFD/P-CPT | 10/10/96 | 15.0 | 9.2 |
| 16CPT-09 | FFD/P-CPT | 10/10/96 | 14.7 | 9.4 |
| 16CPT-10 | FFD/P-CPT | 10/10/96 | 14.8 | 9.0 |
| 16CPT-11 | FFD/P-CPT | 10/10/96 | 14.9 | 8.6 |
| 16CPT-12 | FFD/P-CPT | 10/10/96 | 14.9 | 8.8 |
| 16CPT-13 | FFD/P-CPT | 10/10/96 | 14.5 | 9.2 |
| 16CPT-14 | FFD/P-CPT | 10/10/96 | 14.9 | 8.4 |
| 16CPT-15 | FFD/P-CPT | 10/10/96 | 14.4 | 8.6 |
| 16CPT-16 | FFD/P-CPT | 10/10/96 | 14.7 | 8.8 |
| 16CPT-17 | FFD/P-CPT | 10/10/96 | 14.6 | 12.8 |
| 16CPT-18 | FFD/P-CPT | 10/10/96 | 17.9 | 13.0 |
| 16CPT-19 | FFD/P-CPT | 10/10/96 | 18.1 | 7.8 |
| 16CPT-20 | FFD/P-CPT | 10/10/96 | 14.6 | 10.2 |
| 16CPT-21 | FFD/P-CPT | 10/10/96 | 14.6 | 10.4 |
| 16CPT-22 | FFD/P-CPT | 10/10/96 | 14.5 | 10.6 |
| 16CPT-23 | FFD/P-CPT | 10/10/96 | 14.7 | 10.6 |
| 16CPT-24 | FFD/P-CPT | 10/11/96 | 20.3 | 10.6 |
| 16CPT-25 | FFD/P-CPT | 10/15/96 | 14.8 | 10.6 |
| 16CPT-26 | FFD/P-CPT | 10/15/96 | 14.7 | 10.6 |
| 16CPT-27 | FFD/P-CPT | 10/15/96 | 14.6 | 9.0 |
| 16CPT-28 | FFD/P-CPT | 10/15/96 | 14.9 | 9.0 |
| 16CPT-29 | FFD/P-CPT | 10/15/96 | 14.8 | 4.0 |
| 16CPT-30 | FFD/P-CPT | 10/15/96 | 20.8 | 5.0 |
| 16CPT-31 | FFD/P-CPT | 10/15/96 | 17.4 | 9.0 |
| 26HP-01 | P-CPT | 10/16/96 | 100.0 | 10 : 43 * |
| 26HP-02 | P-CPT | 10/17/96 | 79.1 | 10 : 43 * |
| 26HP-05 | P-CPT | 10/22/96 | 79.0 | 10 : 43 * |
| 26HP-08 | P-CPT | 10/22/96 | 79.6 | 10 : 43 * |
| 26CPT-00 | P-CPT | 10/22/96 | 73.0 | 10 : 43 * |
| 26HP-10 | P-CPT | 10/23/96 | 79.8 | 10 : 43 * |
| 26HP-21 | P-CPT | 10/23/96 | 81.8 | 10 : 43 * |
| 26HP-22 | P-CPT | 10/23/96 | 81.0 | 10 : 43 * |

*Note: Perched ground water table (Upper : Lower).

**Table 1.2 Summary of Water Samples Collected At Naval Weapons Station (NWS) Earle**

| Sample Test Id. | Upper Sample Interval (ft) | Mid Sample Interval (ft) | Lower Sample Interval (ft) | Date Sample Collection |
|---|---|---|---|---|
| 26HP-01 | | 23.6 to 25.6 | 77 to 79 | 10/16/96 & 10/17/96 |
| 26HP-02 | 16.0 to 17.5 | 24 to 25 | 68 to 70 | 10/18/96 |
| 26HP-03 | 10 to 12 | 24.6 to 25.5 | 68.5 to 70.5 | 10/18/96 |
| 26HP-04 | | | 69 TO 71 | 10/24/96 |
| 26HP-05 | | | 68 to 70 | 10/23/96 |
| 26HP-08 | | | 71 to 73 | 10/24/96 |
| 26HP-12 | | 50 to 52 | 71 to 73 | 10/24/96 |
| 26HP-13 | | | 67 to 69 | 10/24/96 |
| 26HP-16 | | | 71 to 73 | 10/24/96 |
| 26HP-20 | 15 to 17 | 24 to 26 | | 10/25/96 |
| 26HP-21 | 15 to 17 | 24 to 26 | | 10/25/96 |
| 26HP-22 | 15 to 17 | 24 to 26 | | 10/25/96 |
| 26HP-23 | 15 to 17 | 23 to 25 | | 10/25/96 |
| 26HP-24 | 15 to 17 | 23 to 25 | | 10/25/96 |
| 26HP-25 | 13 to 15 | 21 to 23 | | 10/25/96 |
| 26HP-26 | 9 to 11 | 19 to 21 | | 10/25/96 |
| 26HP-27 | | 24 to 26 | | 10/25/96 |
| 26HP-28 | | 24 to 26 | | 10/25/96 |

# SECTION 2
# TESTING EQUIPMENT AND PROCEDURES

## INTRODUCTION

The electric cone penetrometer test (CPT) was originally developed for use in soft soil. Over the years, cone and push system designs have evolved to the point where they can now be used in strong cemented soils and even soft rock. ARA's penetrometer consists of an instrumented probe that is forced into the ground using a hydraulic load frame mounted on a heavy truck with the weight of the truck providing the necessary reaction mass. The probe has a conical tip and a friction sleeve that independently measure vertical resistance beneath the tip as well as frictional resistance on the side of the probe as functions of depth. A schematic view of ARA's penetrometer probe is shown in Figure 2.1. A pressure transducer in the cone is used to measure the pore water pressure as the probe is pushed into the ground (P-CPT). The Fuel Fluorescence Detector, a separate module attached directly behind the cone, detects subsurface fuel and hydrocarbon contamination. See Figure 2.2 for a schematic view of the FFD.

## PIEZO-ELECTRIC CONE PENETROMETER TEST

The cone penetrometer tests are conducted using the ARA penetrometer truck. The penetrometer equipment is mounted inside a van body attached to a ten-wheel truck chassis with a diesel engine. Ballast in the form of metal weights are added to the truck to achieve an overall push capability of 60,000 lbs. Penetration force is supplied by a pair of large hydraulic cylinders bolted to the truck frame.

The penetrometer probe is of standard dimensions having a 1.75-inch diameter, 60° conical tip, and a 1.75-inch diameter by 5.27-inch long friction sleeve. The shoulder between the base of the tip and the porous filter is 0.08 inch long. A 1.85-inch diameter expander, located behind the top of the friction sleeve and shown in Figure 2.1, pushes the penetration hole open

and reduces the frictional drag on the push tubes behind the probe. The penetrometer is normally advanced vertically into the soil at a constant rate of 48 inches/minute, although this rate must sometimes be reduced as hard layers are encountered. The electric cone penetrometer test is conducted in accordance with ASTM D3441 (Ref. 1).

Inside the probe, two load cells independently measure the vertical resistance against the conical tip and the side friction along the sleeve. Each load cell is a cylinder of uniform cross section inside the probe which is instrumented with four strain gages in a full-bridge circuit. Forces are sensed by the load cells and the data are transmitted from the probe assembly via a cable running through the push tubes. The analog data are digitized, recorded, and plotted by computer in the penetrometer truck. A set of data is normally recorded each second, for a minimum resolution of about one data point every 0.8 inch of cone advance. The depth of penetration is measured using a linear displacement transducer mounted inside one of the push cylinders.

Electronic data acquisition equipment for the cone penetrometer consists of a computer with a graphics monitor and a rack of eight signal conditioners. Analog signals are transmitted from the probe to the signal conditioners where the CPT data are amplified and filtered at 1 Hz. Once amplified, the analog signals are transmitted to a high speed analog-to-digital converter board, where the signals are digitized; usually at the rate of one sample per second for the penetration data. The digital data are then read into memory and written to the internal hard disk for future processing. Upon completion of the test the penetration data are plotted. The digital data are brought to ARA's New England Division in South Royalton, Vermont, for analysis and preparation of report plots.

## Saturation of the Piezo-Cone

Penetration pore pressures are measured with a pressure transducer located behind the tip in the lower end of the probe. Water pressures in the soil are sensed through a 250 μin porous polyethylene filter that is 0.25-inch high and 0.202-inch thick. The pressure transducer is connected to the porous filter through a pressure port as shown in Figure 2.1. The pressure port and the filter are filled with a high viscosity silicone oil.

For the pressure transducer to respond rapidly and correctly to changing pore pressures upon penetration, the filter and pressure port must be saturated with oil upon assembly of the probe. A vacuum pump is used to de-air the silicone oil before use and also to saturate the porous filters with oil. The probe is assembled with the pressure transducer facing upwards and the cavity above the pressure transducer is filled with de-aired oil. A previously saturated filter is then placed on a tip and oil is poured over the threads. When the cone tip is screwed into place, excess oil is ejected through the pressure port and filter, thereby forcing out any trapped air.

The piezo cone was calibrated at the onset of the field investigation. Periodically, the cone was resaturated and fitted with a new tip and sleeve. This was done at the discretion of the field crew and site representative. The high viscosity of the silicone oil coupled with the small pore space in the filter prevents the loss of saturation as the cone is pushed through dry soils. Saturation of the cone can be verified with a calibration check at the completion of the penetration. Extensive field experience has proven the reliability of this technique.

## Field Calibrations

Many factors can effectively change the calibration factors used to convert the raw instrument readouts, measured in volts, to units of force or pressure. As a quality control measure, as well as a check for instrument damage, the load cells and the pressure transducer are routinely calibrated in the field. Calibrations are completed with the probe ready to insert into

the ground so that any factor affecting any component of the instrumentation system will be included and detected during the calibration.

The tip and sleeve load cells are calibrated with the conical tip and friction sleeve in place on the probe. For each calibration, the probe is placed in the push frame and loaded onto a precision reference load cell. The reference load cell is periodically calibrated in ARA's laboratory against instruments traceable to NIST standards. To calibrate the pore pressure transducer, the saturated probe is inserted into a pressure chamber with air pressure supplied by the compressor on the truck. The reference transducer in the pressure chamber is also periodically calibrated against an NIST traceable instrument in ARA's laboratory. Additionally, the linear displacement transducer used to measure the depth of penetration, is periodically checked against a tape measure. All records of device and load cell calibrations are located at ARA's New England Division.

Each instrument is calibrated using a specially developed computer code that displays the output from the reference device and the probe instrument in graphical form. During the calibration procedure, the operator checks for linearity and repeatability in the instrument output. At the completion of each calibration, this code computes the needed calibration factors using a linear regression algorithm. At a minimum, each probe instrument is calibrated at the beginning of each day of field testing. Furthermore, the pressure transducer is recalibrated each time the porous filter is changed and the cone resaturated. Calibrations are also performed to verify the operation of any instrument if any damage is suspected.

**Penetration Data Format**

Data are presented as profiles of tip resistance and sleeve friction. A sample presentation of data is shown in Figure 2.3. Tip resistance is obtained by dividing the vertical force on the conical tip by the effective tip area (2.35 $in^2$). The offset between the depth at the tip and the depth at the friction sleeve is corrected by shifting the sleeve friction profile downward so that it corresponds to the depth at the centroid of the tip. In addition to the resistance and sleeve

friction, a friction ratio profile is presented for each location. This is simply the sleeve friction expressed as a percentage of the tip resistance. In uncemented soils the friction ratio can be used to determine soil type.

The penetration pore pressure that is measured as the probe is advanced is also plotted in Figure 2.3. As shown in Figure 2.1, the piezo-cone probe senses the pore pressure immediately behind the tip. Currently, there is no accepted standard for the location of the sensing element. ARA chose to locate the sensing element behind the tip since the filter is protected from the direct thrust of the penetrometer and the measured pore pressure can be used to correct the tip resistance data (discussed in the next section) as recommended in Reference 2. The magnitude of the penetration pore pressure is a function of the soil compressibility and, most importantly, permeability. In freely draining soil layers, the measured pore pressures will be very close to the hydrostatic pressure computed from the elevation of the water table. When low permeability soil layers are encountered, excess pore pressures generated by the penetration process can not dissipate rapidly and this results in measured pore pressures which are significantly higher than the hydrostatic pressures. Whenever the penetrometer is stopped to add another section of push tube, or when a pore pressure dissipation test is run, the excess pore pressure may begin to dissipate. When the penetration is resumed, the pore pressure quickly rises to the level measured before the penetrometer was stopped. This process causes some of the spikes that appear in the penetration pore pressure data.

## Pore Pressure Correction of Tip Stress

Cone penetrometers, by necessity, must have a joint between the tip and sleeve. Pore pressure acting behind the tip decreases the total tip resistance that would be measured if the penetrometer was without joints. The influence of pore pressure in these joints is compensated for by using the net area concept (Ref. 2). The corrected tip resistance is given by:

$$q_T = q_c + u\left(1 - \frac{A_n}{A_T}\right) \tag{2.1}$$

where: $q_T$ = corrected tip resistance (psi)

$q_c$ = measured tip resistance (psi)

$u$ = penetration pore pressure measured behind the tip (psi)

$A_n$ = net area behind the tip not subjected to the pore pressure (1.911 $in^2$)

$A_T$ = projected area of the tip (2.35 $in^2$).

Hence, for the ARA cone design, the tip resistance is corrected as:

$$q_T = q_c + u\,(.1870) \tag{2.2}$$

Laboratory calibrations have verified Equation 2.2 for ARA's piezo-cone design.

A joint also exists behind the top of the sleeve (see Figure 2.1). However, since the sleeve is designed to have the same cross sectional area on both ends, the pore pressures acting on the sleeve cancel out. Laboratory tests have verified that the sleeve is subjected to equal end area effects. Thus, no correction for pore pressure is needed for the sleeve friction data.

The net effect of applying the pore pressure correction is to increase the tip resistance. Generally, this correction is only significant when the measured tip resistance is very low.

**Numerical Editing of the Penetration Data**

Any time that the cone penetrometer is stopped or pulled back during a test, misleading data can result. For instance, when the probe is stopped to add the next push tube section, or when a pore pressure dissipation test is run, the excess pore pressures will dissipate towards the hydrostatic pore pressure. When the penetration is resumed, the pore pressure generally rises very quickly to the pressures experienced prior to the pause in the test. In addition, the probe is sometimes pulled back and cycled up and down at intervals in deep holes to reduce soil friction on the push tubes. This results in erroneous tip stress data when the cone is advanced in the previously penetrated hole.

To eliminate this misleading data from the penetration profile, the data is numerically edited before it is plotted or used in further analysis. Each time the penetrometer stops or backs up, as apparent from the depth data, the penetration data is not plotted. Plotting of successive data is resumed only after the tip is fully re-engaged in the soil by one tip length (1.22 in) of new penetration. This algorithm also eliminates any data acquired at the ground surface before the tip has been completely inserted into the ground. The sleeve data is similarly treated and this results in the first data point not occurring at the ground surface, as can be seen in the tip and sleeve profiles of Figure 2.3. These procedures ensure that all of the penetration data that is plotted and used for analysis was acquired with the probe advancing fully into undisturbed soil. The second part of Figure 2.3 illustrates the resulting soil classification and soil properties for this exploration.

**Fuel Fluorescence Detector (FFD)**

The Fuel Fluorescence Detector (FFD) is a field screening system designed to detect subsurface fuel and hydrocarbon contamination. The FFD is specifically designed for use with direct cone penetrometer technology, for the detection of fluorescence emitted by hydrocarbons when excited by an ultra violet light source. The FFD can be optimized to detect specific contaminants, or scan a wide range of fuel products such as diesel, jet fuel, unleaded gasoline and other petroleum products.

The FFD system consists of a down-hole module and an up-hole controller. The module can be attached directly to a CPT cone for simultaneous stratigraphy analysis and contaminant screening, or can be operated without the cone using an optional tip. The filter excitation light from a 254 nm ultraviolet light source is focused on the soil or groundwater at the surface of the probe through a sapphire window, and the resulting fluorescence is returned through a fiber optic conductor to the controller. Various optional filters narrow the spectrum of the light signal to isolate the fluorescence of the pollutants of interest. A photomultiplier tube and amplifier circuit convert the optical signal to a voltage (0-5 VDC) which is displayed on the front panel of the controller and recorded on a standard data acquisition system. Offset controls allow the operator

to adjust for background fluorescence levels, and internal safety logic protects the optical sensor if exposed to direct sunlight.

The FFD responds to total petroleum hydrocarbons (TPH) to as low as 100 ppm in sandy soils, as shown in Figure 2.4. This enables the delineation of subsurface hydrocarbon layers in real time. Multiple profiles across the site can be used to develop a three dimensional model of the plume. Figure 2.4 shows typical continuous output of fluorescence versus depth for the NWS Earle test site.

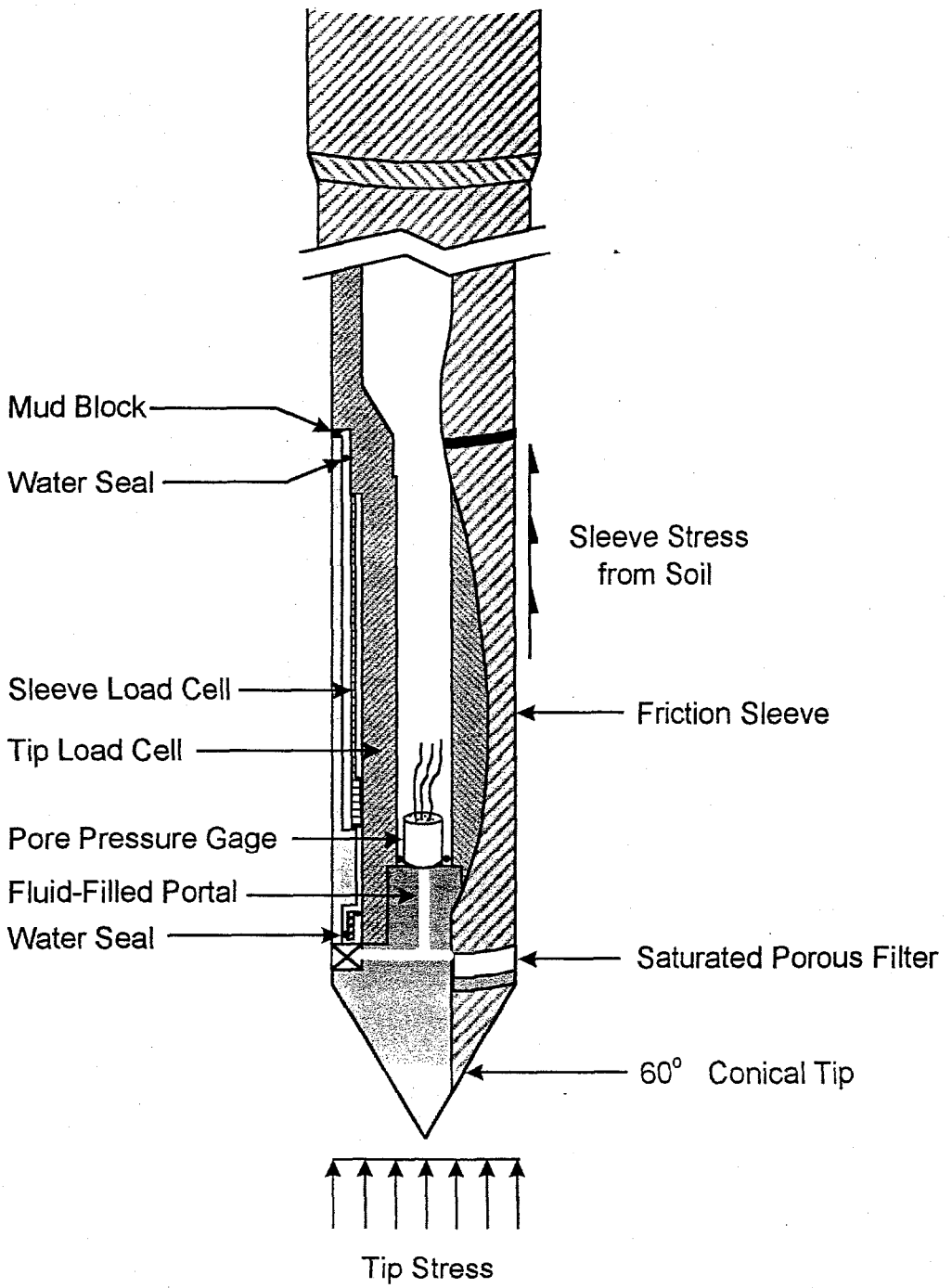


Figure 2.1 Schematic of ARA's Cone Penetrometer Probe.

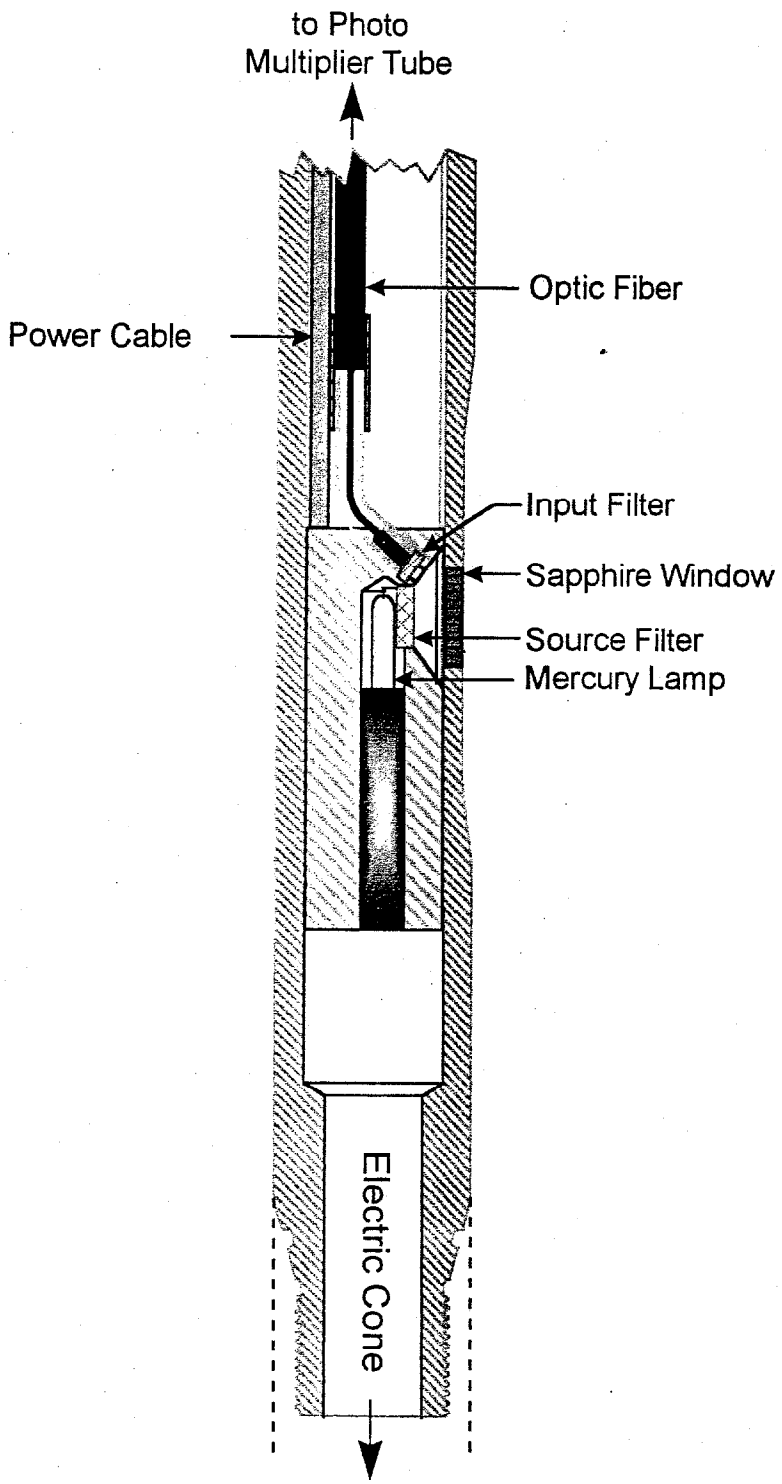


Figure 2.2 Schematic of ARA's Fuel Fluorescence Detector.

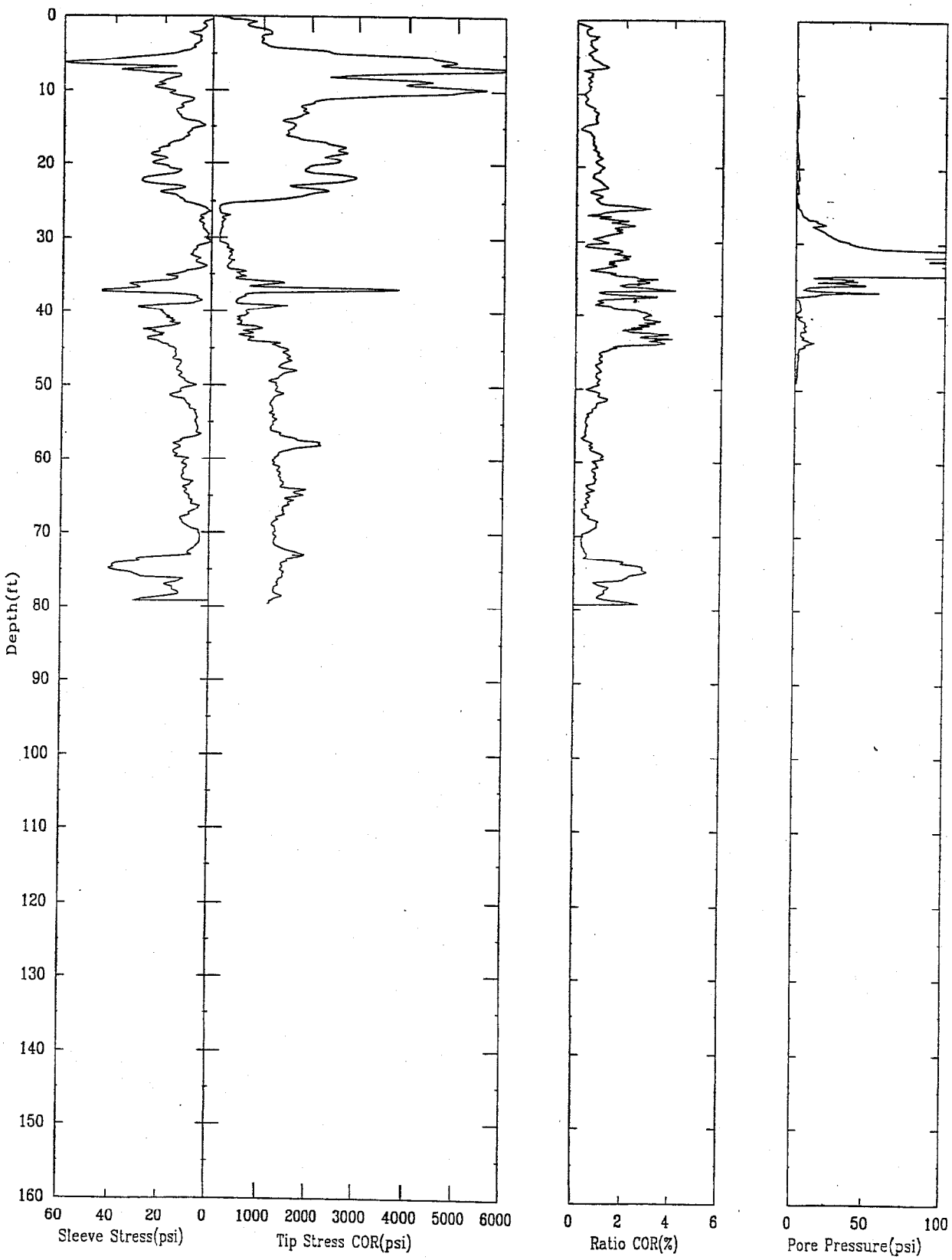


Figure 2.3 Typical P-CPT Penetration Profile.

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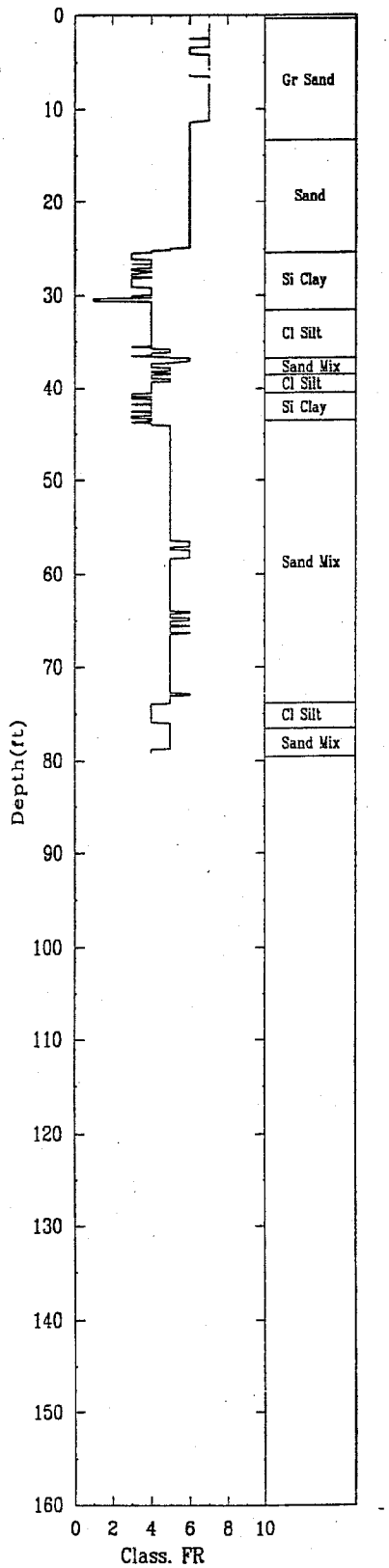



Figure 2.3 Typical P-CPT Penetration Profile (concluded).

File 5220603B.ECP

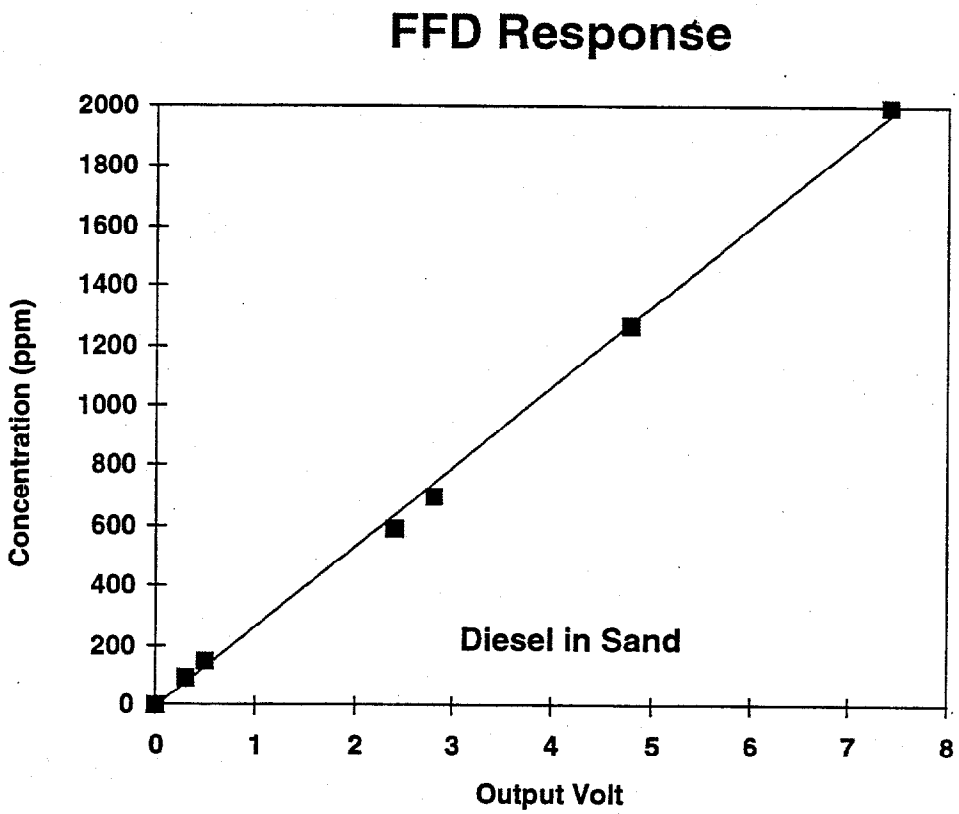



Figure 2.4 Calibration Relationship Showing Detector Capabilities Down to 100ppm.

## SECTION 3

## TECHNIQUES FOR ESTIMATING IN SITU SOIL PROPERTIES

### OVERVIEW

Presented in this section is a detailed discussion of a typical Piezo-Electric Cone Penetrometer Test (P-CPT) methods for estimating in situ soil properties. All calculations were conducted using a soil density of 115 pcf above the water table and 62.6 pcf below the water table.

### LOCATION OF THE SITE WATER TABLE

Generally, the static water table at a given site can be identified from the penetration pore pressures, which will be equal to the hydrostatic pore pressure in freely draining soil layers. When no such layers are present at a site, pore pressure dissipation tests can be performed to determine hydrostatic pressures at depth. In the case of the NWS Earle site, the depth of the ground water was obtained by the Brown & Root Environmental site representative. For the eight deep pushes in site 26, a perched water table is apparent. An upper ground water table (GWT) is present at approximately 10 ft bgs, with a lower GWT at 43.0 ft bgs, separated by a confining layer. The confining layer begins 23 to 28 ft bgs, depending on the test, and ranges in thickness of 5 to 10 feet.

### RELATIVE DENSITY

Relative density determinations were made using an empirical relationship developed by Robertson and Campanella, 1988 (Ref. 2). An empirical fit to laboratory data is shown below and also in Figure 3.1 which presents the data set used to determine the empirical relationship.

$$Rd = -98 + 66 \log_{10} \frac{q_c}{(\sigma_{vo}')^{0.5}} \qquad \textbf{(3.1)}$$

where: $Rd$ = relative density (%)

$q_c$ = uncorrected tip resistance (psi)

$\sigma'_{vo}$ = effective overburden stress (psi)

Relative density results are contained in the ASCII data files provided to Brown & Root Environmental.

## SOIL CLASSIFICATION

Plots of normalized tip resistance versus friction ratio and normalized tip resistance versus penetration pore pressure can be used to determine soil classification as a function of depth. Both methods of soil classification are based on empirical charts developed by Robertson. The soil classification is determined from the charts (see Figure 3.2) by using the normalized corrected tip stress in bars and pore pressure ratio, $B_q$ or normalized friction ratio of $f_{SN}$. The pore pressure ratio is defined as:

$$B_q = \frac{u_{meas} - u_o}{q_T - \sigma_{vo}} \tag{3.2}$$

where: $u_{meas}$ = measured penetration pore pressure

$u$ = static pore pressure, determined from the water table elevation

$q_T$ = corrected tip resistance

$\sigma_v$ = total overburden stress,

and the normalized friction ratio is defined as:

$$f_{SN} = \frac{f_s}{q_T - \sigma_{vo}} \, x\, 100 \tag{3.3}$$

and the normalized tip resistance is defined as:

$$q_{NT} = \frac{q_T - \sigma_{vo}}{\sigma_{v'o}} \tag{3.4}$$

The intersection point of the $q_T$ and $B_q$ or $f_{SN}$ values normally falls in a classification zone. The classification zone number corresponds to a soil type as shown in the figure. At some depths, the CPT data will fall outside of the range of the classification chart. When this occurs, no data is plotted and a break is seen in the classification profile. Soil classifications for this work were determined using the friction ratio method in Equation 3.3. Close analysis of these charts indicates that as the classification numbers vary, so does the soil grain size. What is missing in these charts are mixed soils, such as sandy clays or clayey sands. This type of mixed soil represents special cases and may be misclassified as silts.

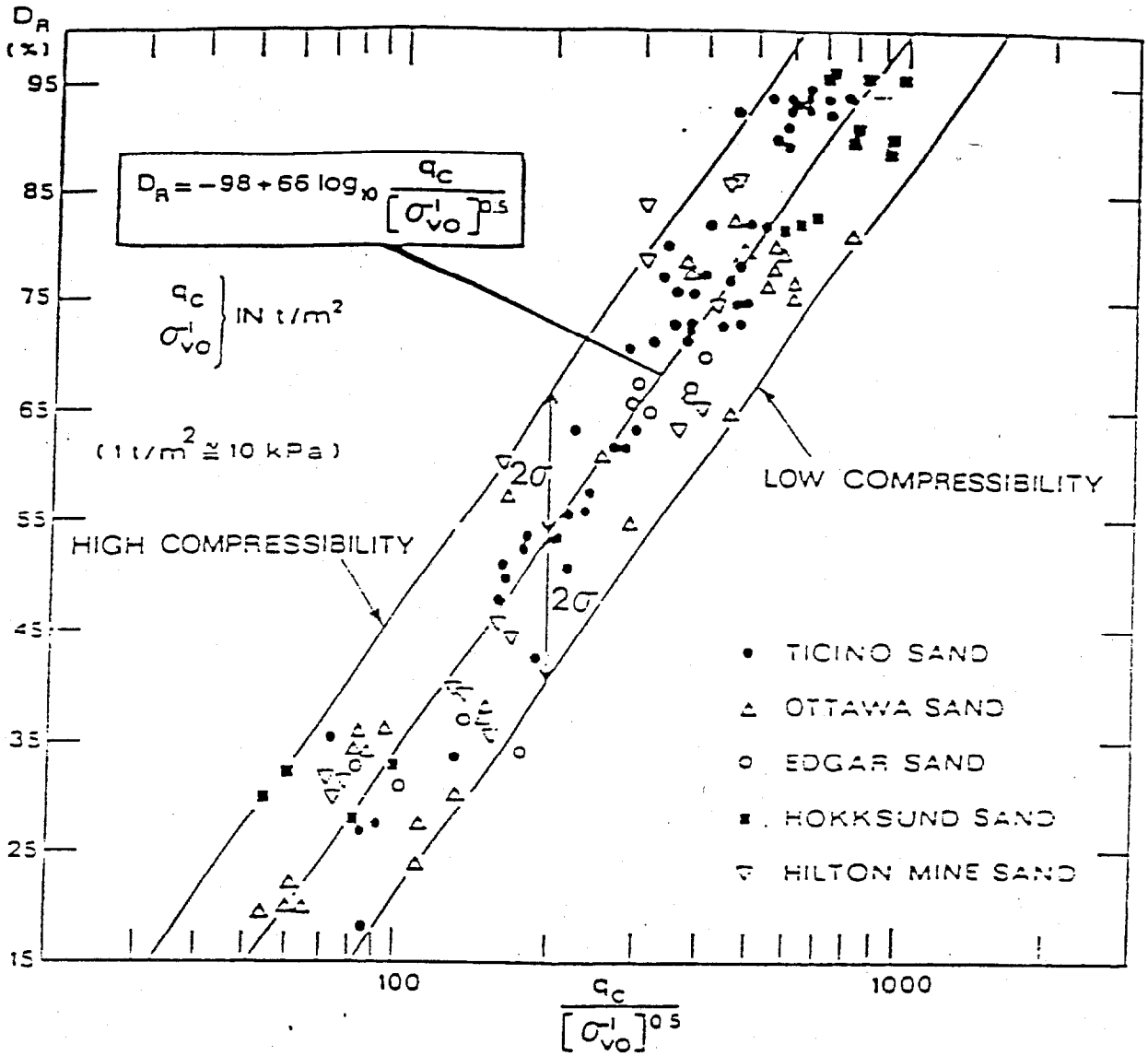
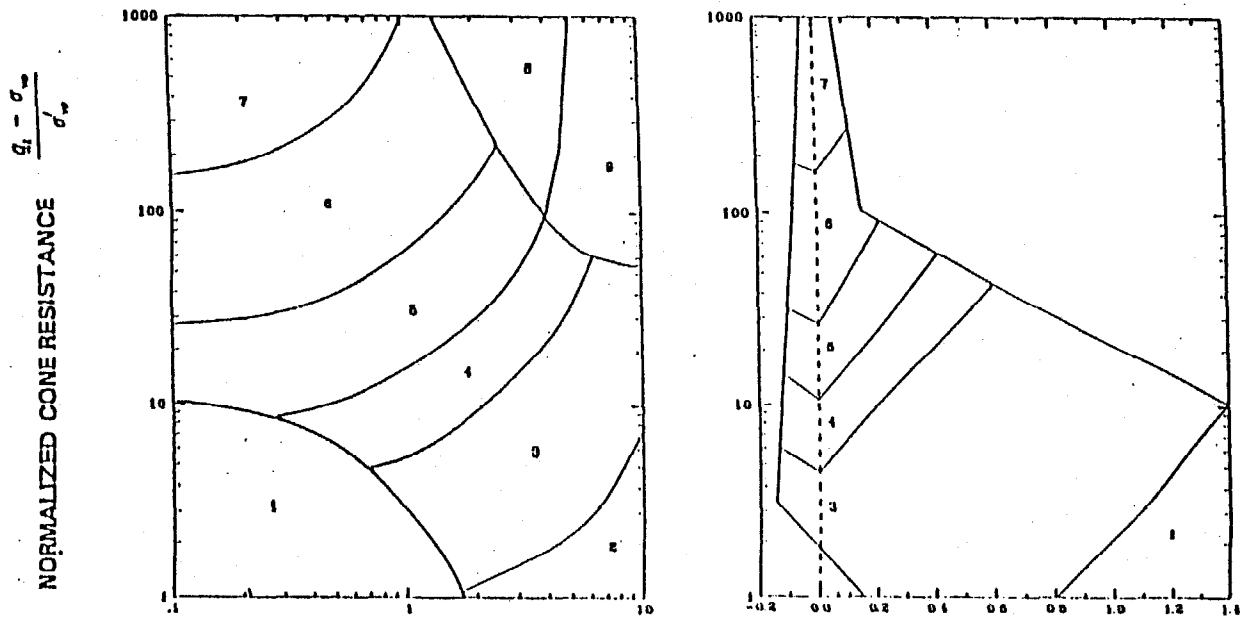



Figure 3.1 Empirical relationship for relative density for normally consolidated, uncemented, unaged, predominately quartz sands (after Robertson and Campanella, 1988).




1. Sensitive, Fine Grained
2. Organic Soils-Peat
3. Clays - Clay to Silty Clay
4. Silty Mixtures - Clayey Silt to Sandy Silt
5. Sand Mixtures - Silty Sand to Sandy Silt
6. Sands - Clean Sand to Silty Sand
7. Gravelly Sand to Sand
8. Very Stiff Sand to Clayey* Sand
9. Very Stiff, Fine Grained*

(*) Heavily Overconsolidated or Cemented

Figure 3.2 Soil Classification Using the Cone Penetration Tests, P.K. Robertson.

## SECTION 4
## DATA SUMMARY

This section describes the analysis of two typical profiles at NWS Earle site. General explanations on how some conclusions are drawn using the data collected from the cone penetrometer are also presented.

A typical shallow profile is shown in Figure 4.1. The upper 3.5 feet of this location are classified as gravely sands. This classification is a result of the high tip stress relative to sleeve friction. Spikes in the friction ratio indicate finer grained soils as seen from 3.5 feet to 4 feet bgs and 5 feet to 6 feet bgs. These layers classify as sand mixes, most likely containing some fine silts. A spike in penetration pore pressure at 3.5 feet bgs is also evidence of a fine grained soil lens. The soils become coarse once again from 6 ft to 8 ft bgs, followed by a sand layer that extends to the exploration termination depth of 14.5 feet.

Continuing with Figure 4.1, the Fuel Fluorescence Detector encountered a contaminated layer at 8.5 ft bgs that extended to approximately 10.5 ft bgs. This contamination is floating on the water table which is at 10.4 ft bgs at this test location. The fact that the FFD shows a "sharp" spike indicates the rise in voltage is actually caused by the presence of a local contaminant. The spike also shows that there is negligible "smearing" on the window of the FFD.

A deep profile, as shown in Figure 2.3, shows a confining layer at approximately 25 feet. Typically, a higher friction ratio indicates a type of clay or fine silts. Another sign of a confining layer is the observation of the a substantial rise in pore pressure at this strata. This high pressure is caused by the clay/silts preventing ground water from dissipating quick enough as the cone penetrometer is pushed. A sand mix is present below the confining layer and is apparent throughout most of the remaining profile.

Depth to the ground water table were given by the Brown & Root site representative. A ground water table of approximately 10 feet was given for this area. Once the probe passed through the confining layer, pore pressure dropped. Soil dilation below 43 feet resulted in negative pore pressure readings. Saturated sand, with the presence of fine grains, will cause this characteristic of dilation as the cone penetrometer advances downward. This dilation effect itself is an indicator that water is present. When probe advancement was stopped, the stable pore pressure calculated to a GWT of 43 feet bgs, not 10 feet. This indicates the presence of a perched water table laying on the surface of the confining layer.

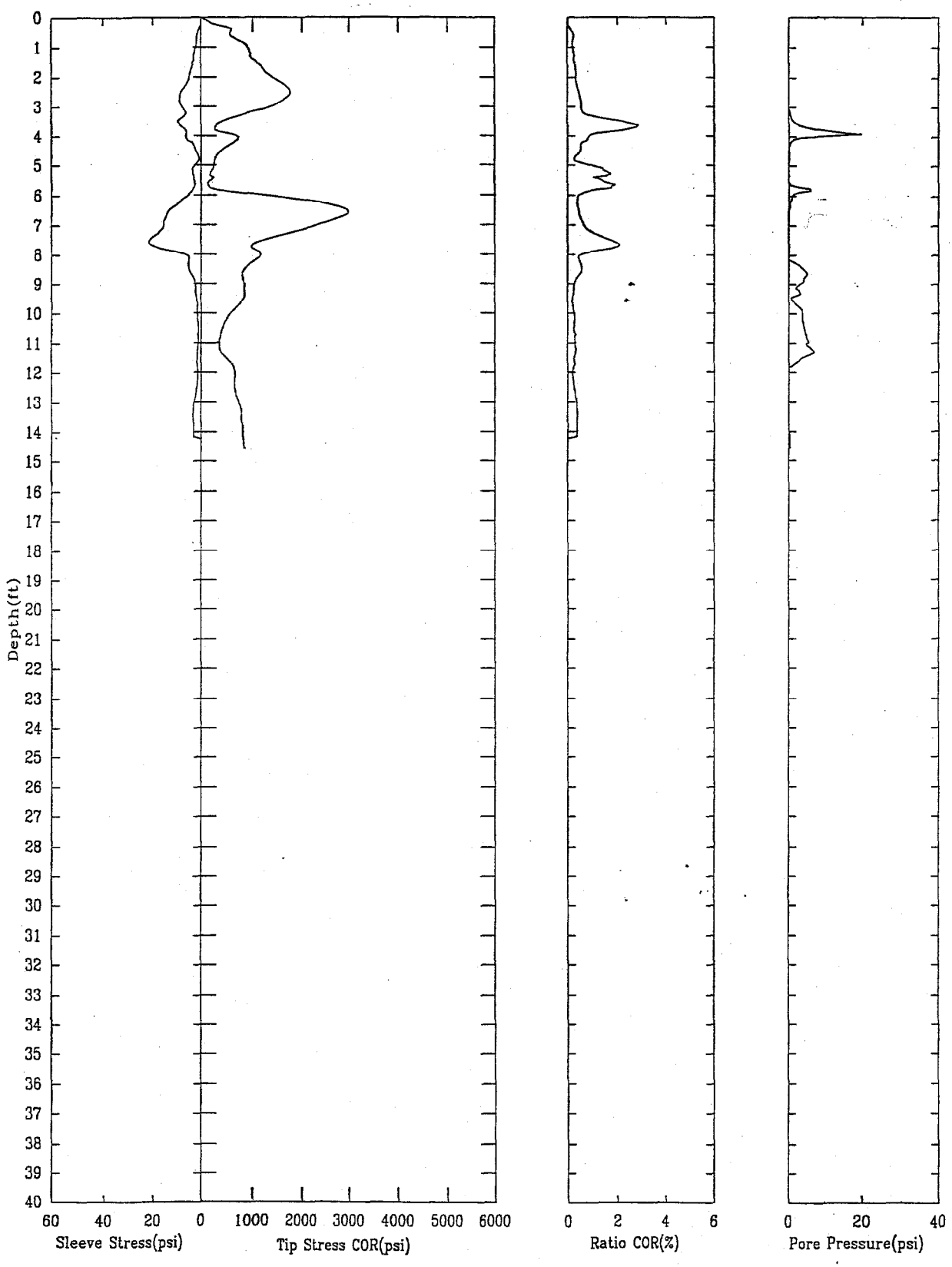



Figure 4.1 Typical Shallow P-CPT Penetration Profile.

File 5100620B.ECP

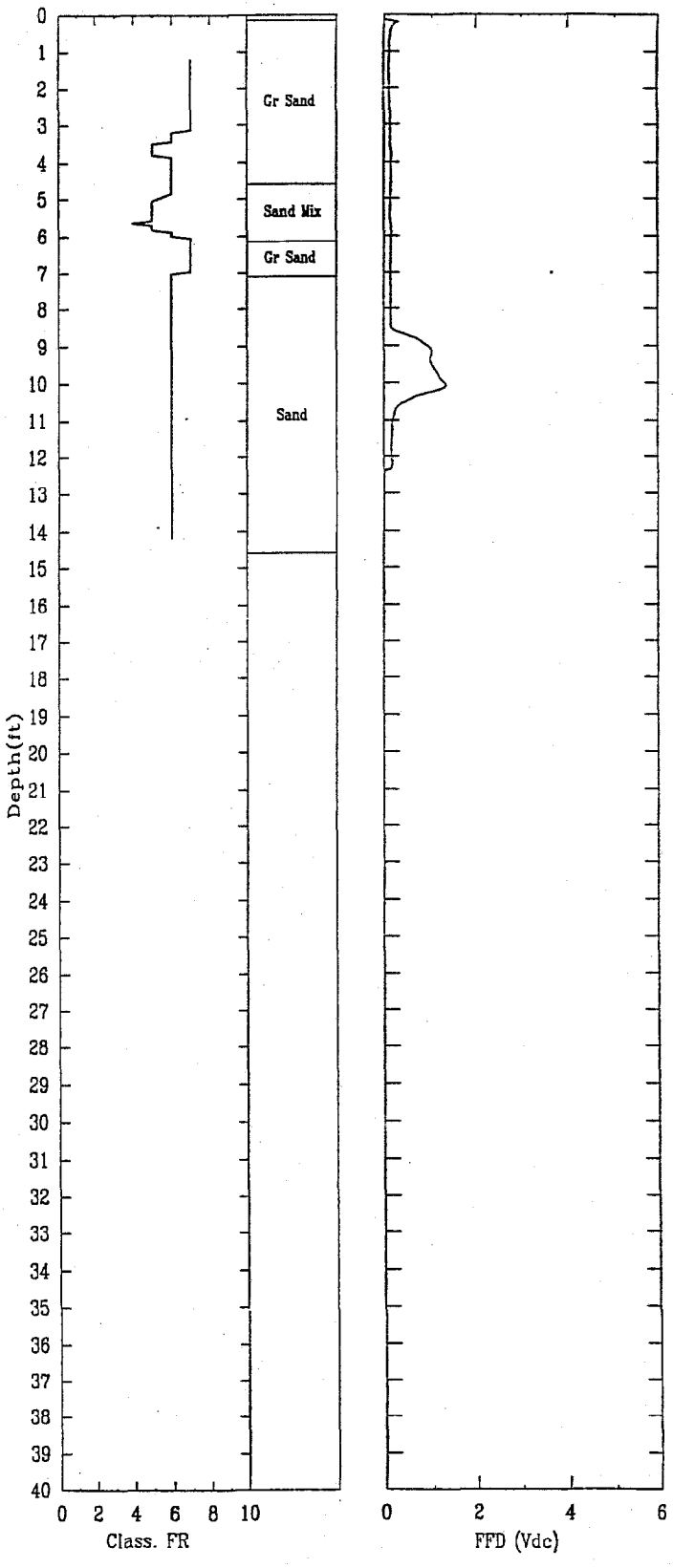



Figure 4.1 Typical Shallow P-CPT Penetration Profile (concluded).

File 5100620B.ECP

## SECTION 5

## LIST OF REFERENCES


1. American Society for Testing Materials, "Standard Method for Deep Quasi-Static Cone and Friction-Cone Penetration Tests of Soil," ASTM Designation: D3441, 1986.

2. Robertson, P.K. and R.G. Campanella, *Guidelines for Using the CPT, CPTU and Marchetti DMT for Geotechnical Design*, Vol. II, University of British Columbia, Vancouver, BC, Canada, March 1988.

3. *Use of In Situ Test in Geotechnical Engineering*, S.P. Clemence, ed., Geotechnical Special Publications No. 6, proceedings of In Situ '86 Conference, sponsored by Geotechnical Engineering Division of the American Society of Civil Engineers, Blacksburg, VA, June 1986.

# APPENDIX A

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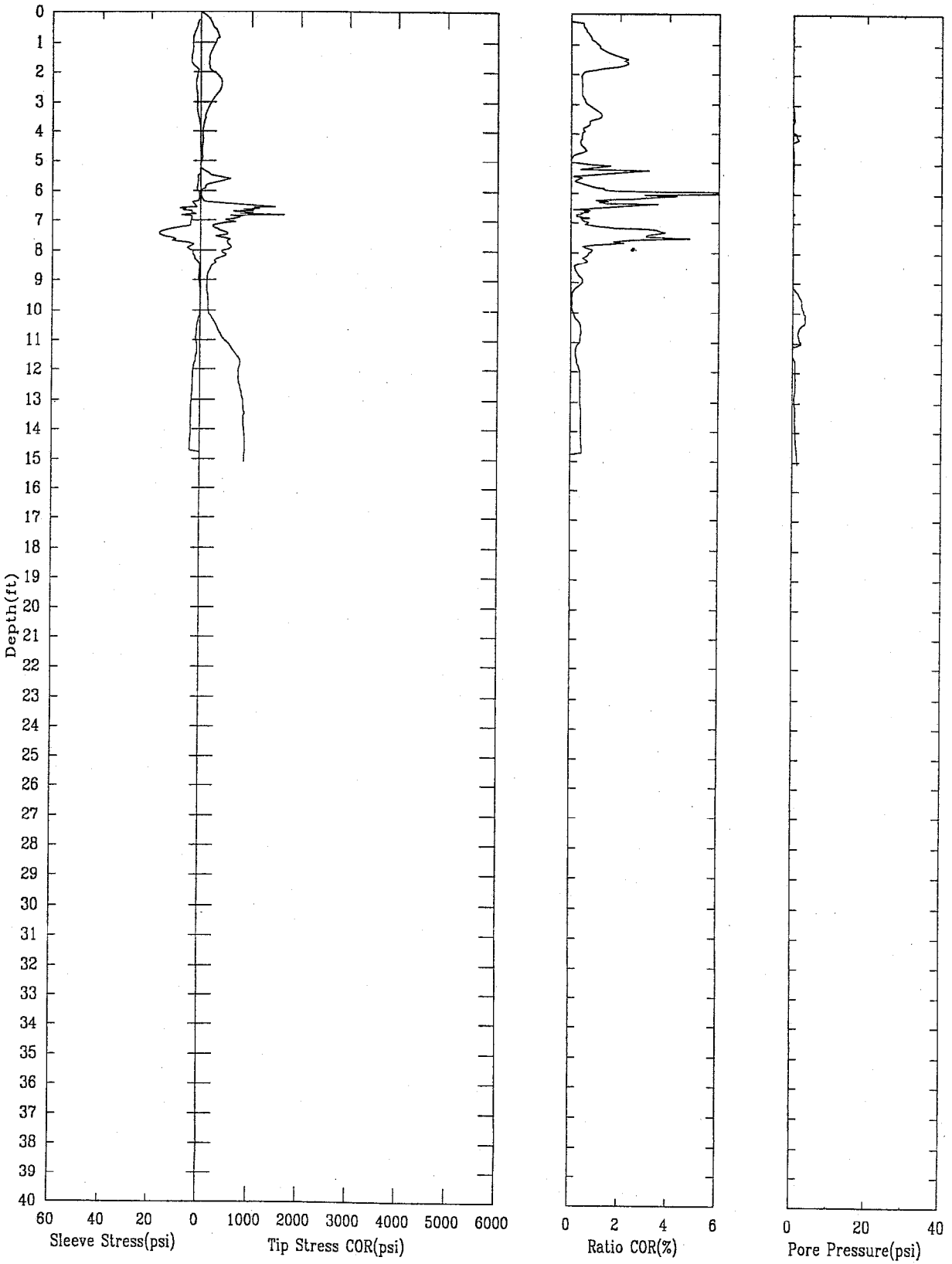


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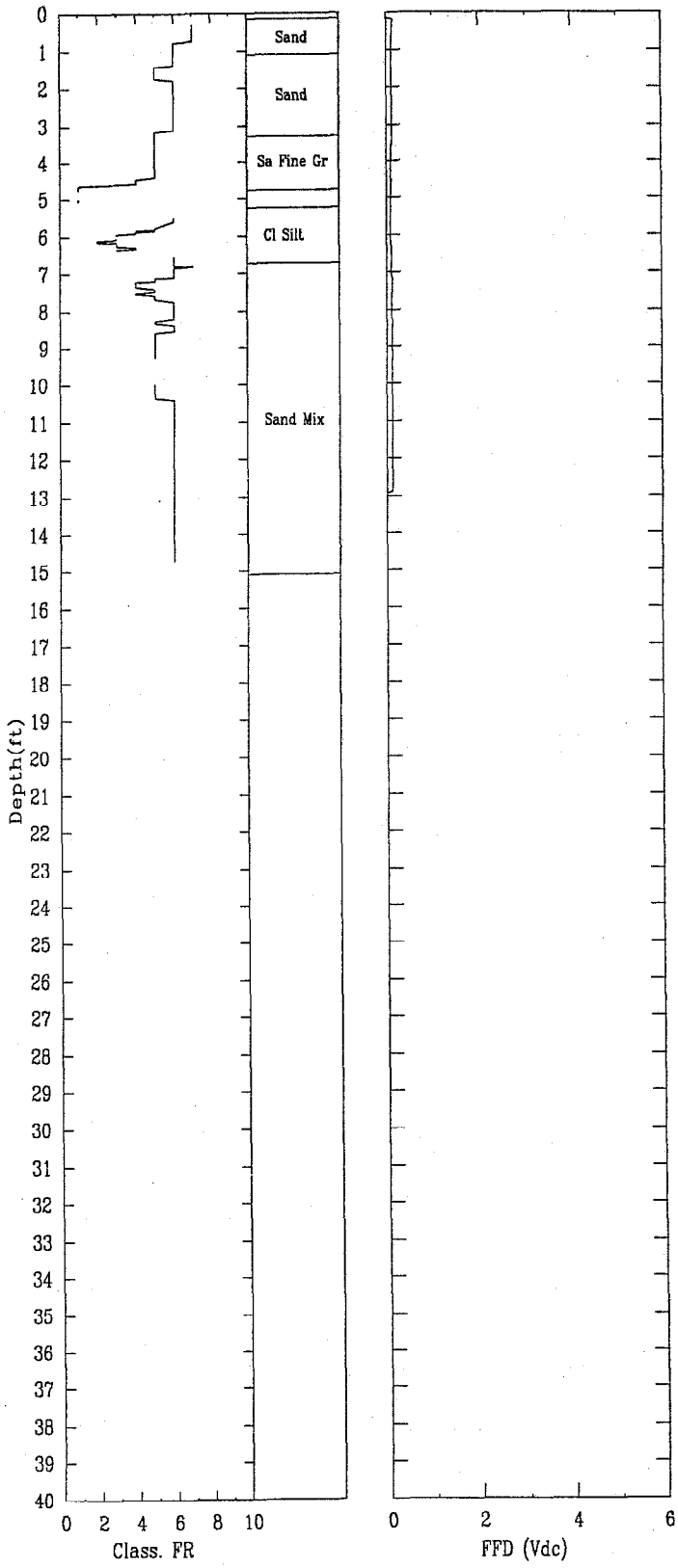


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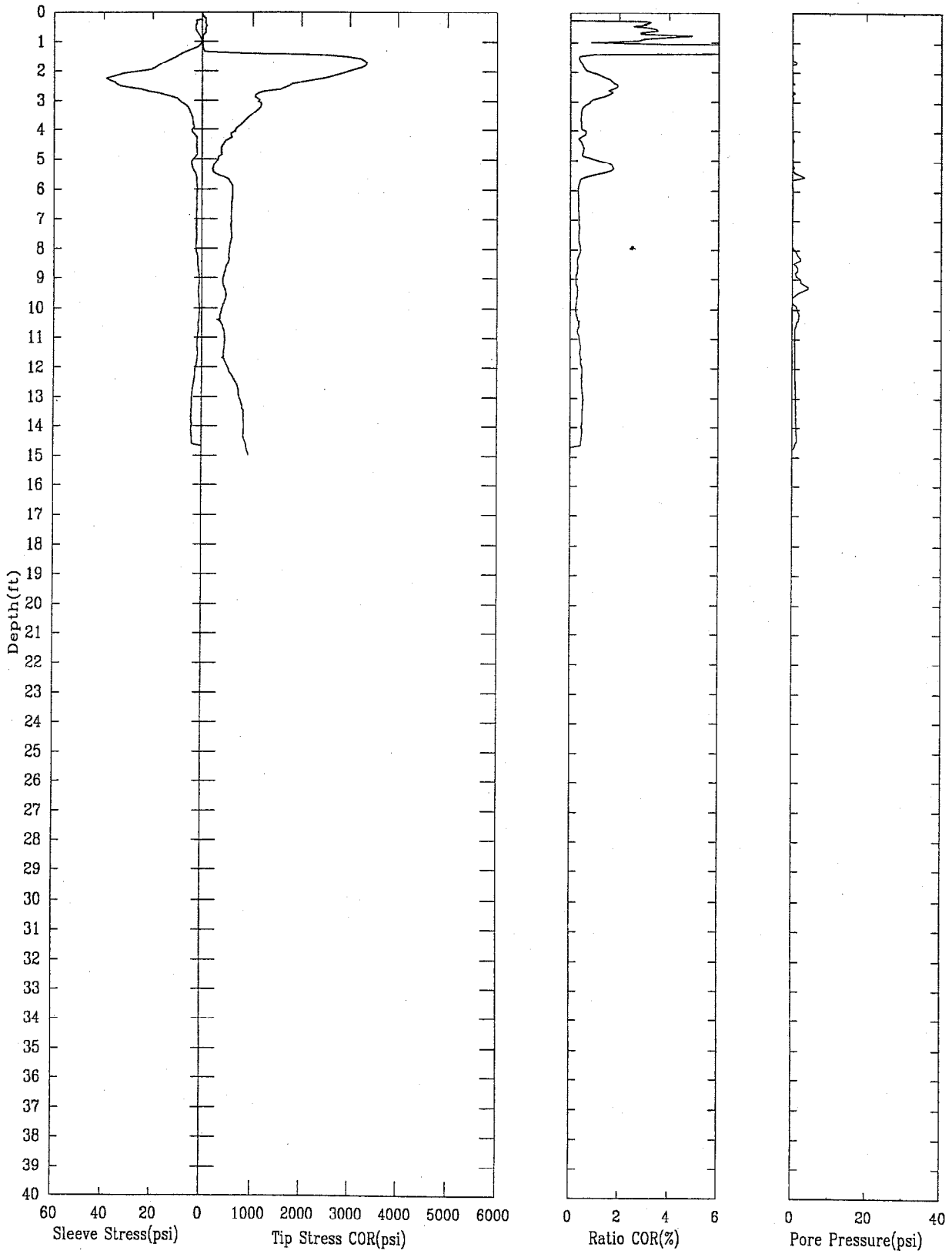


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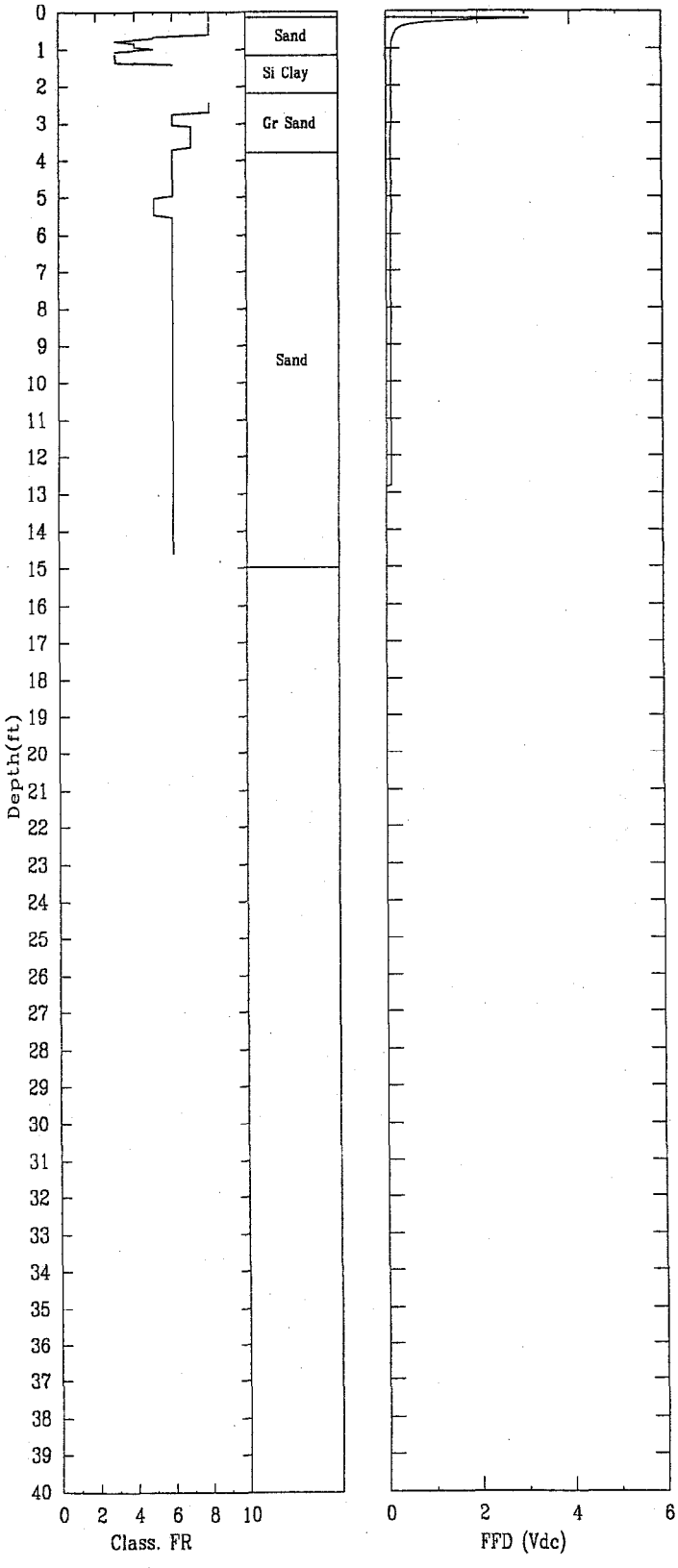


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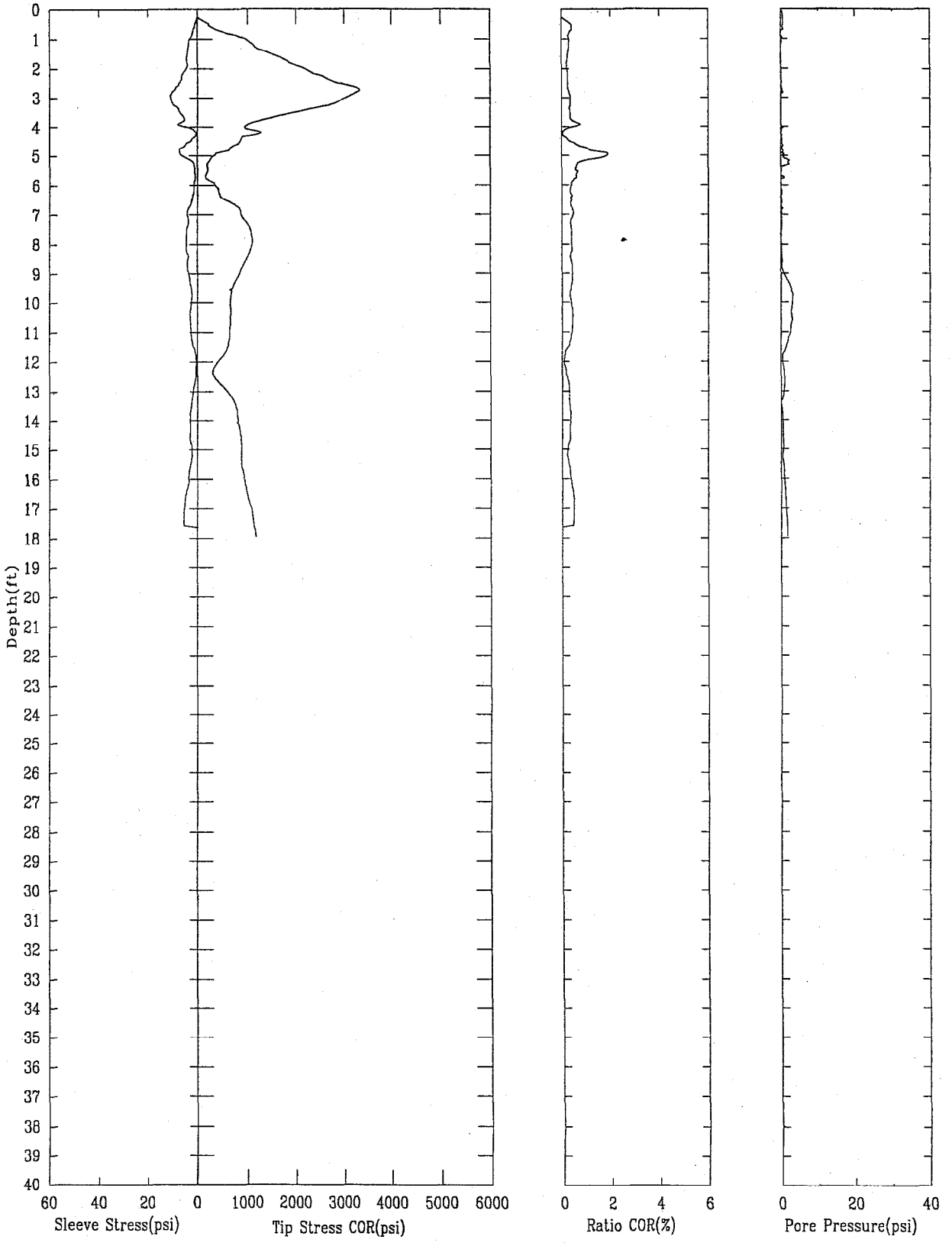


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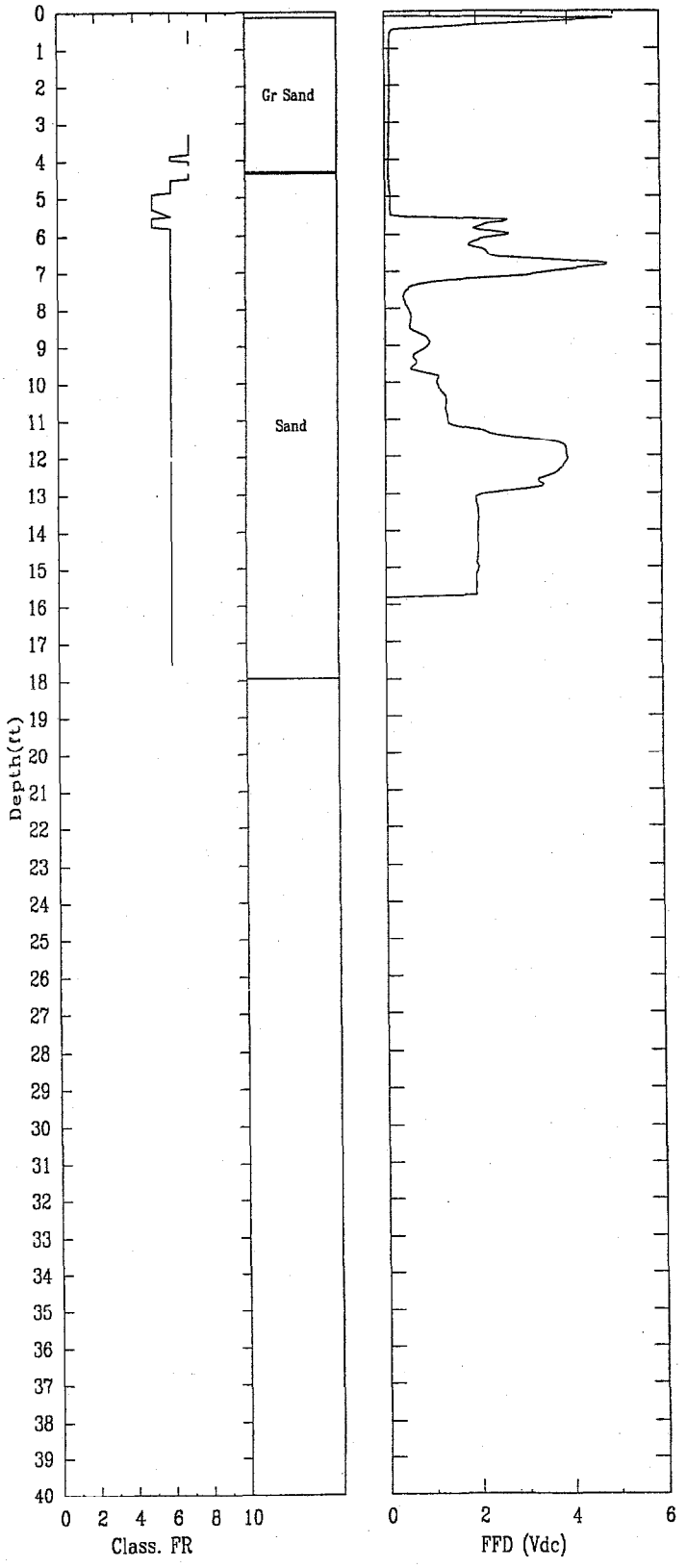


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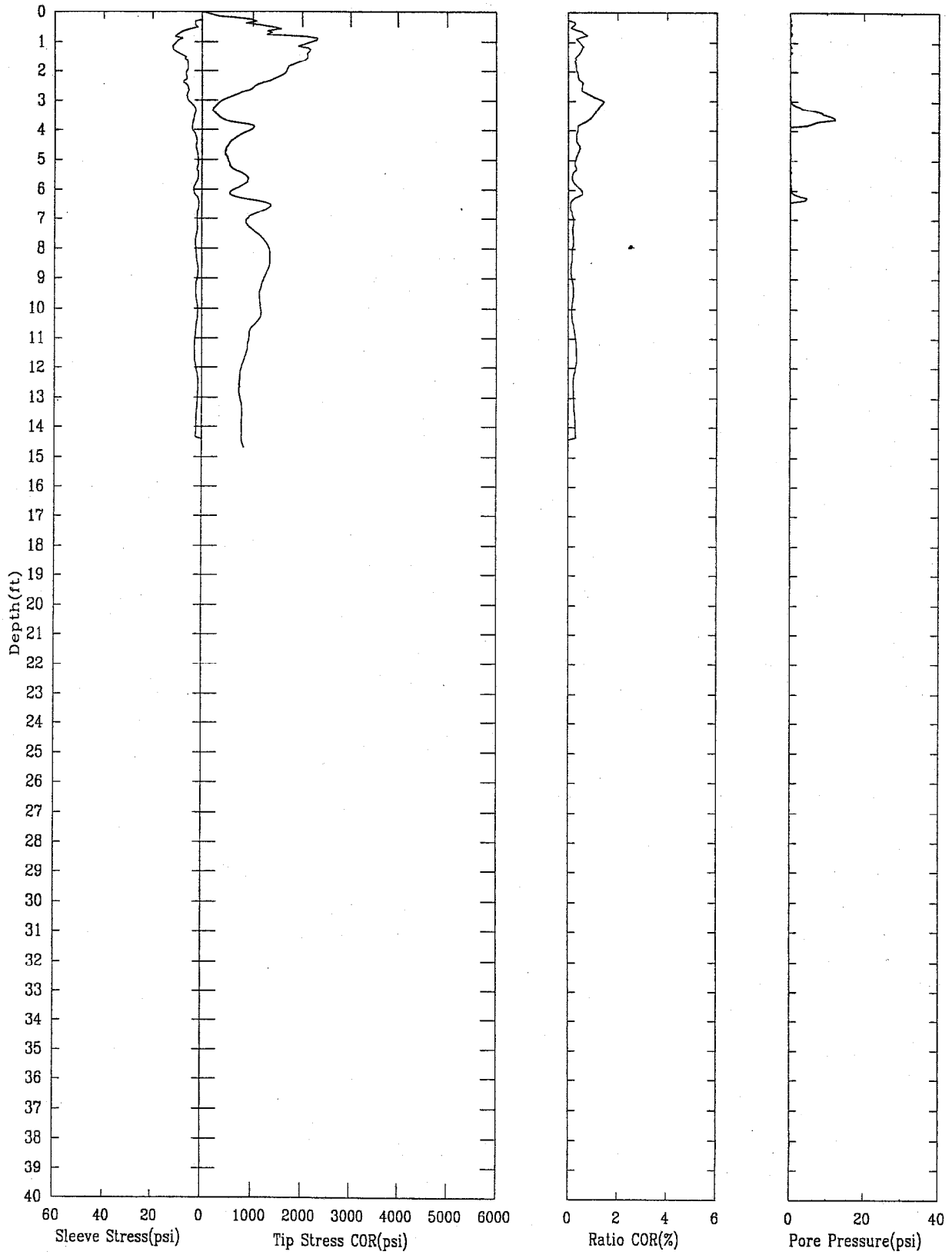


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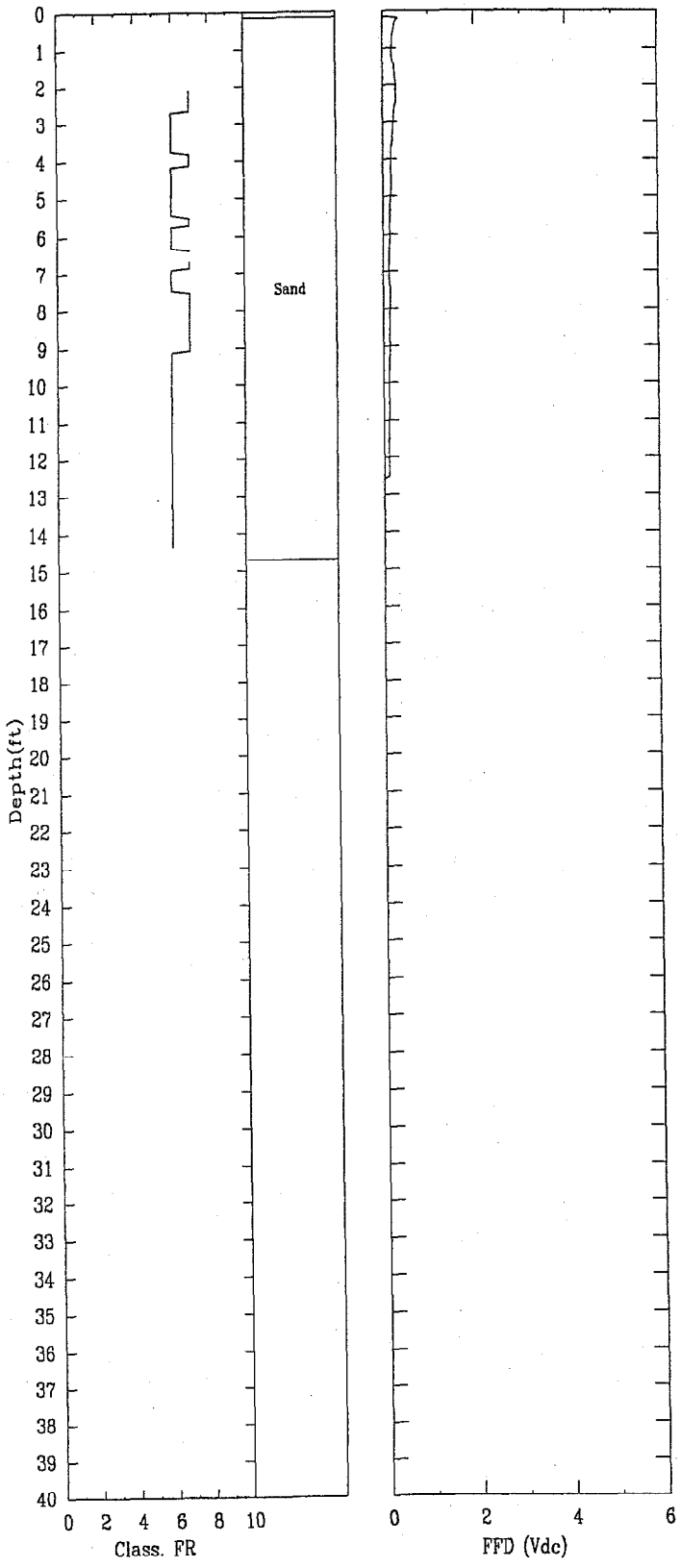


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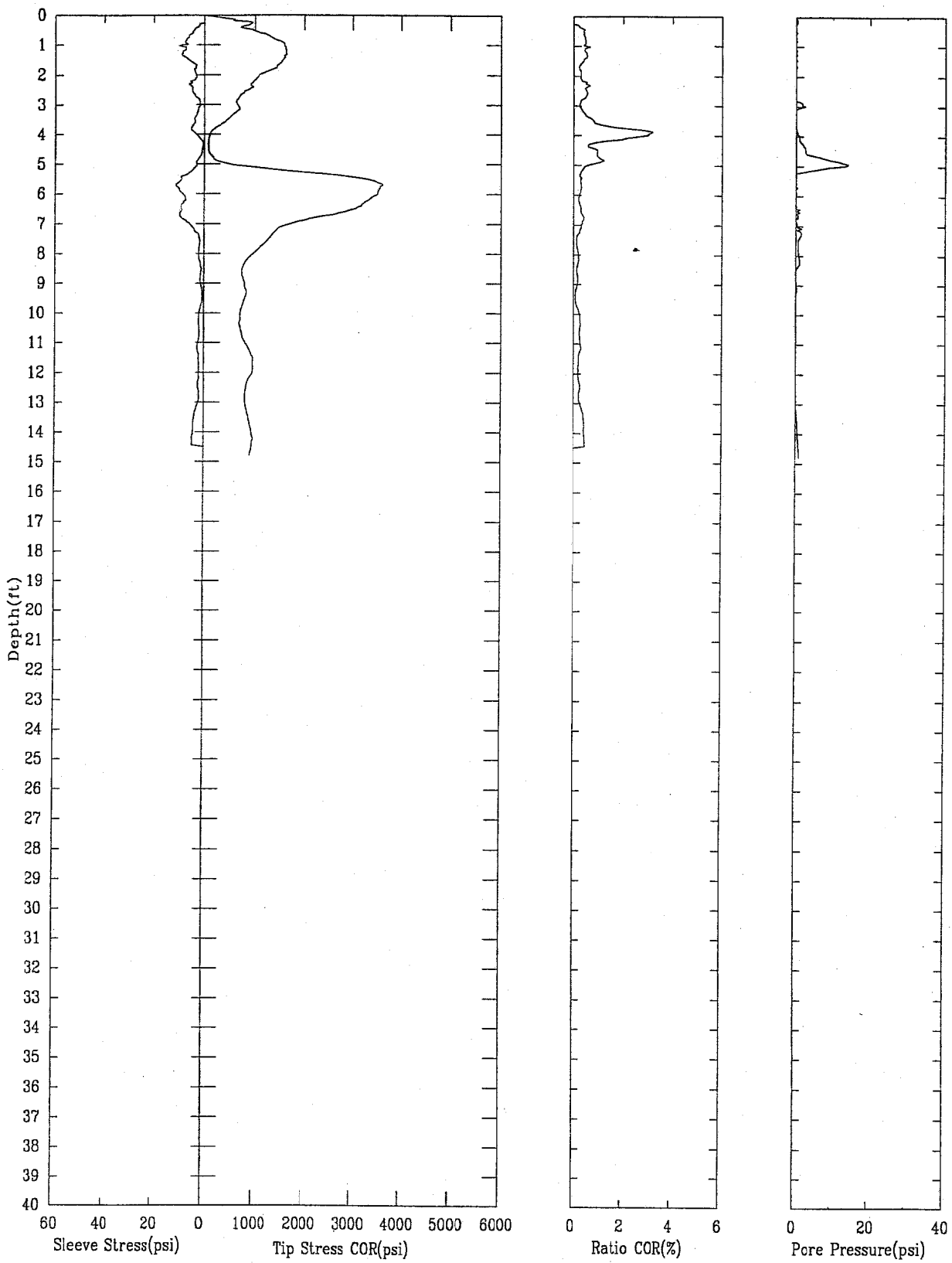


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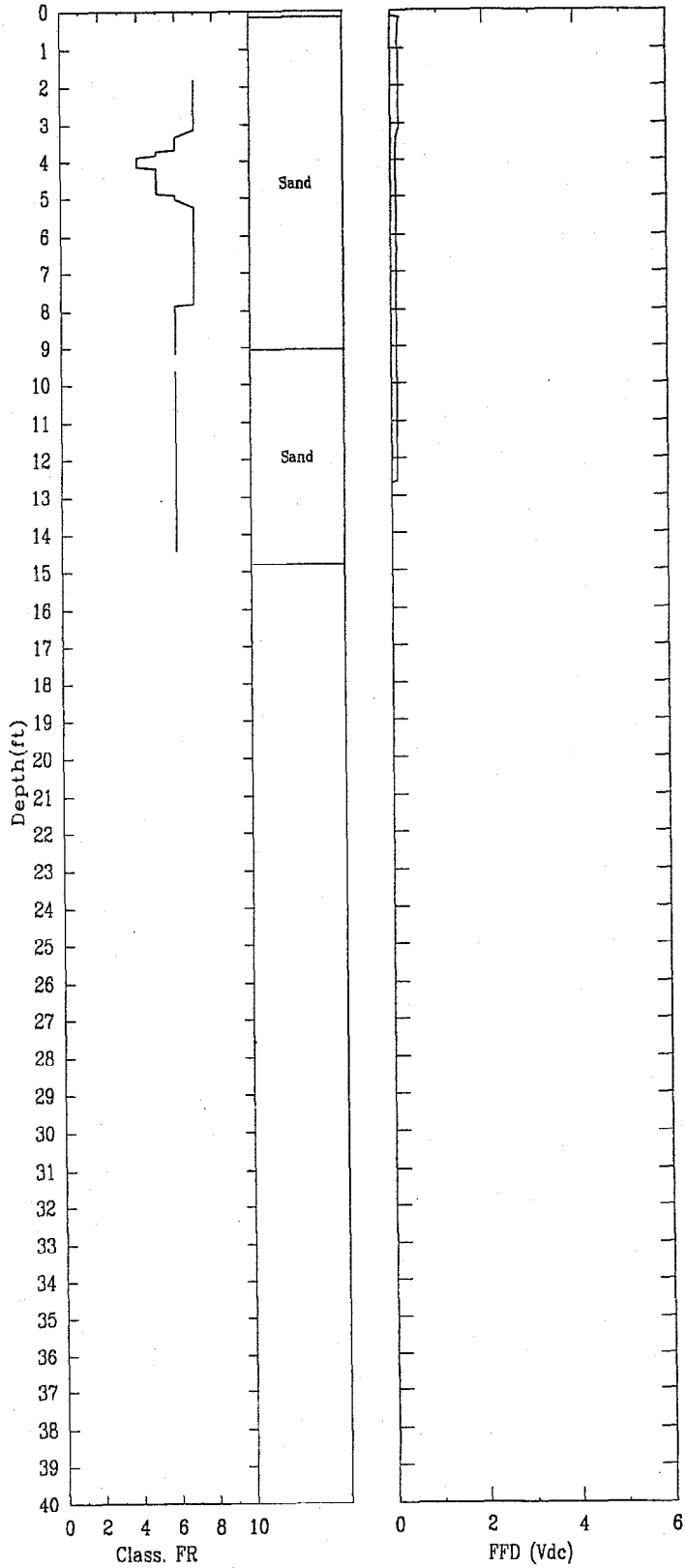


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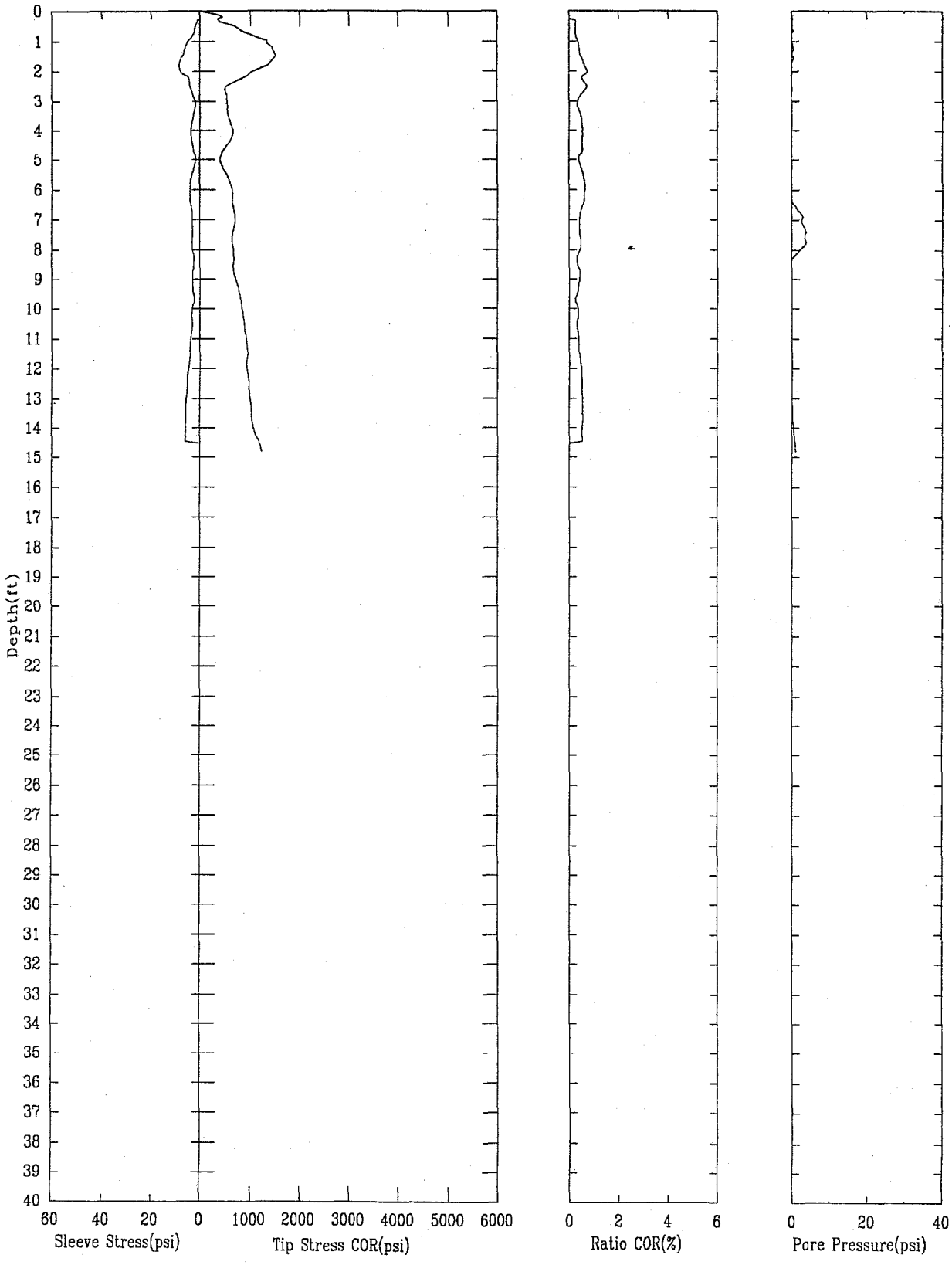


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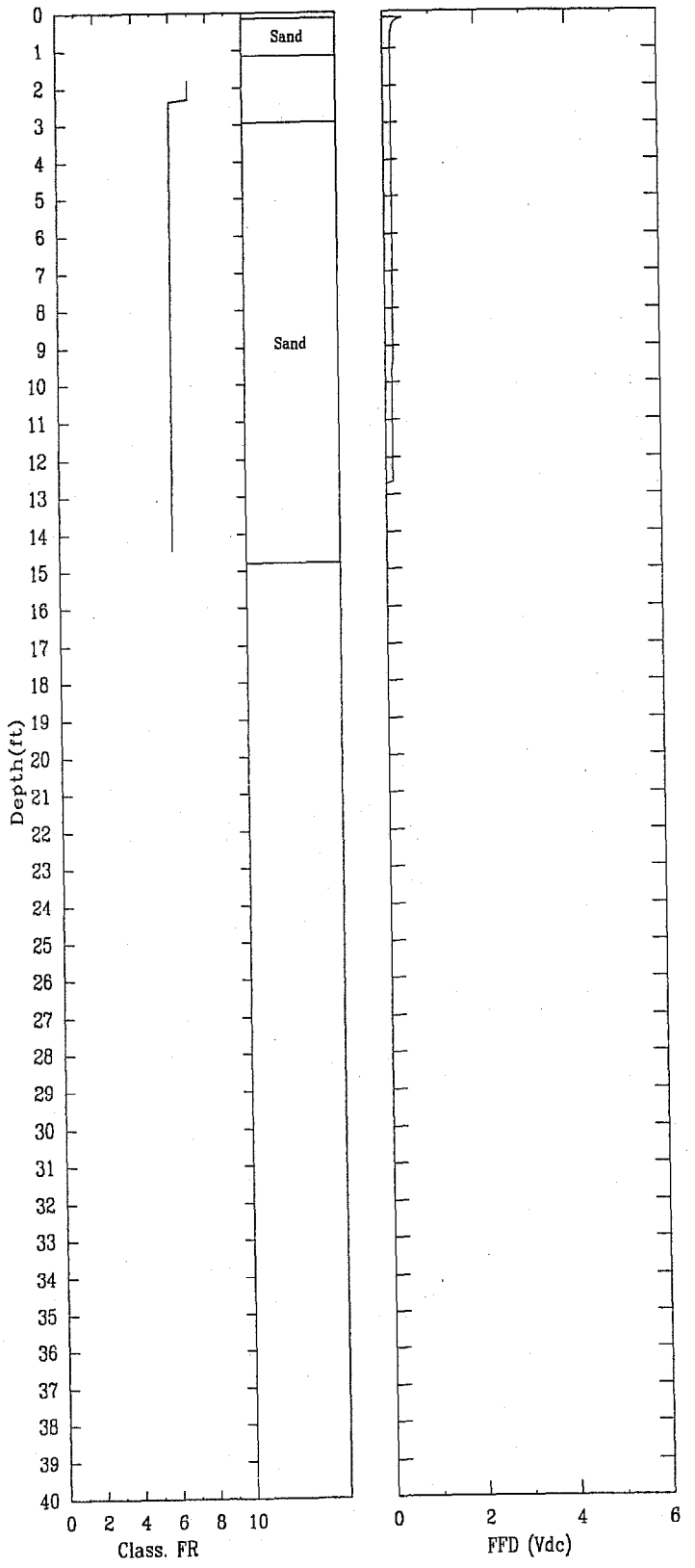


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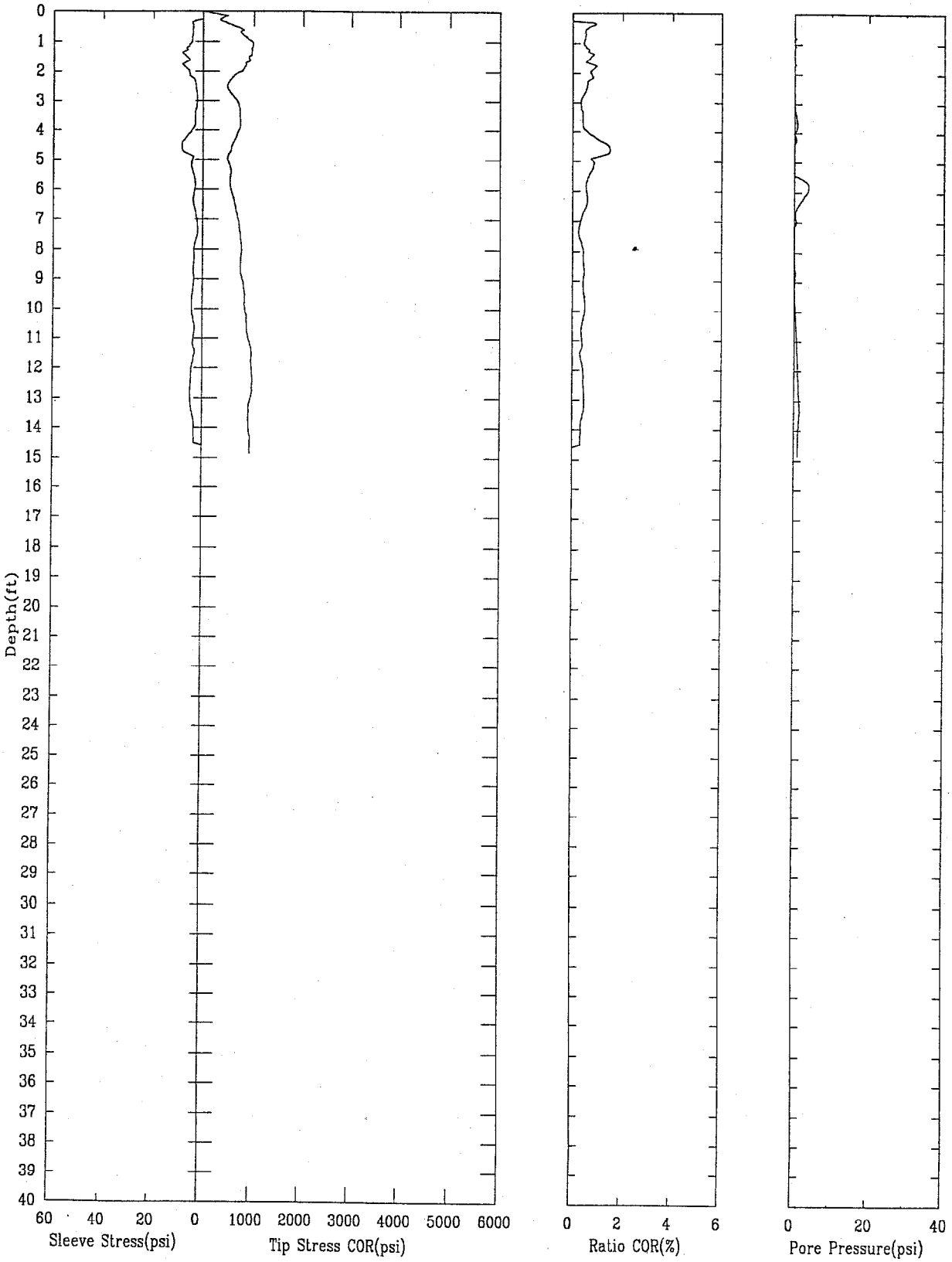


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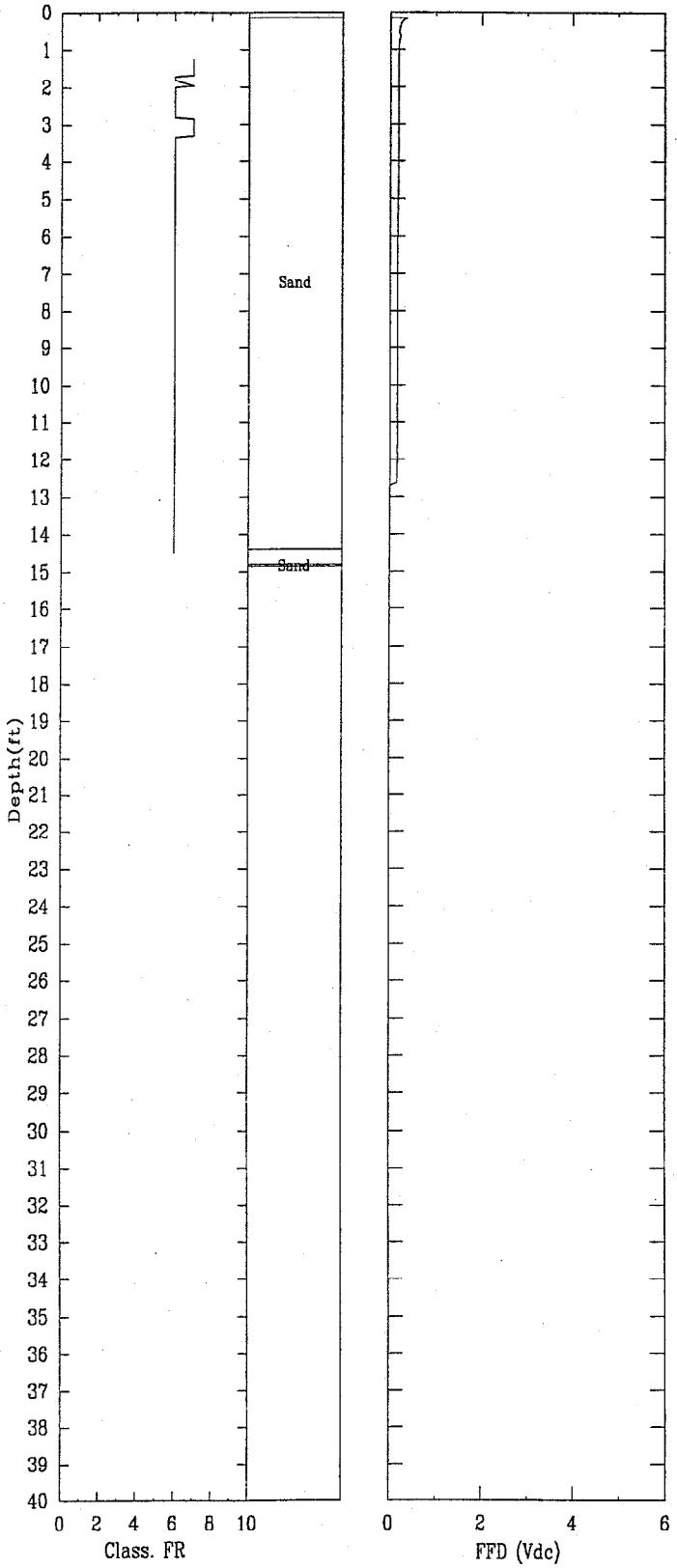


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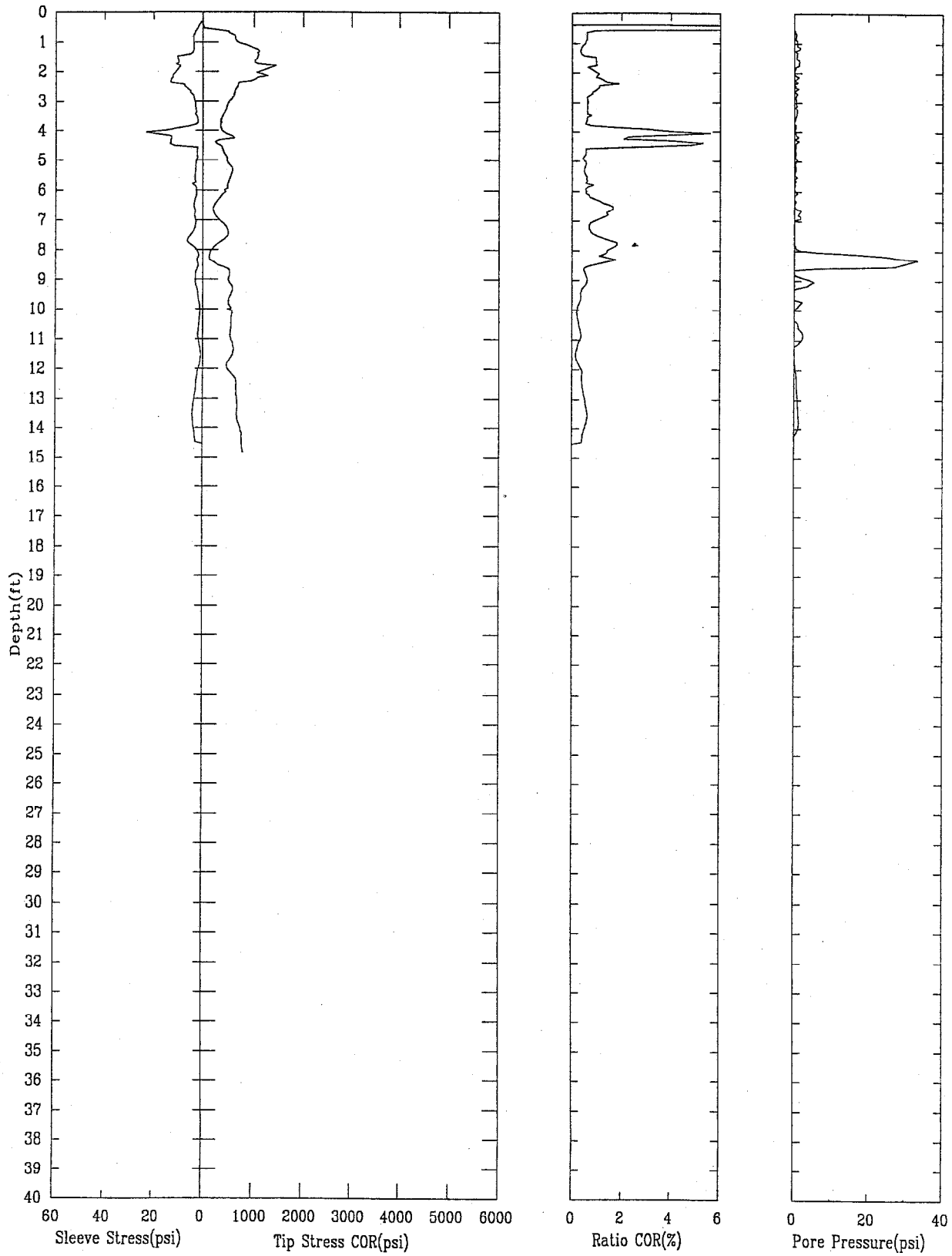


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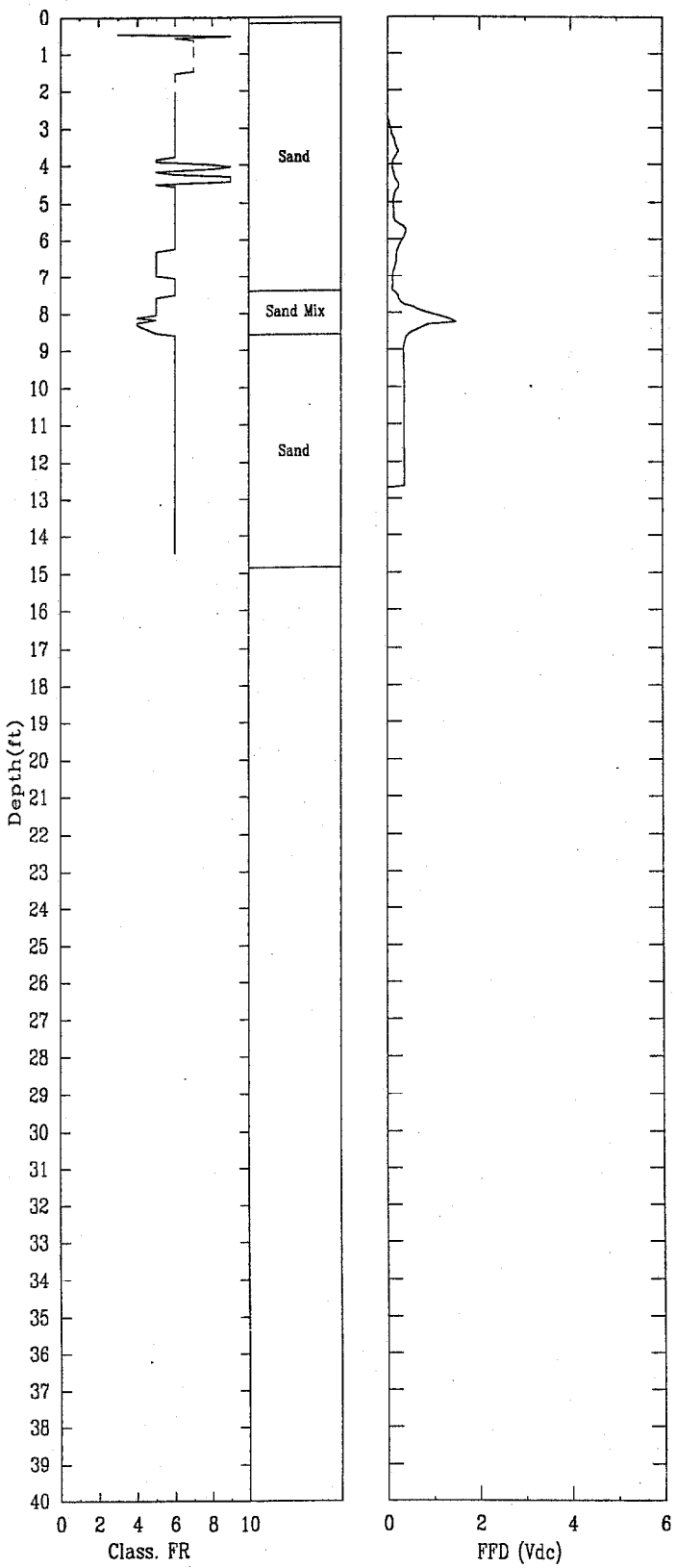


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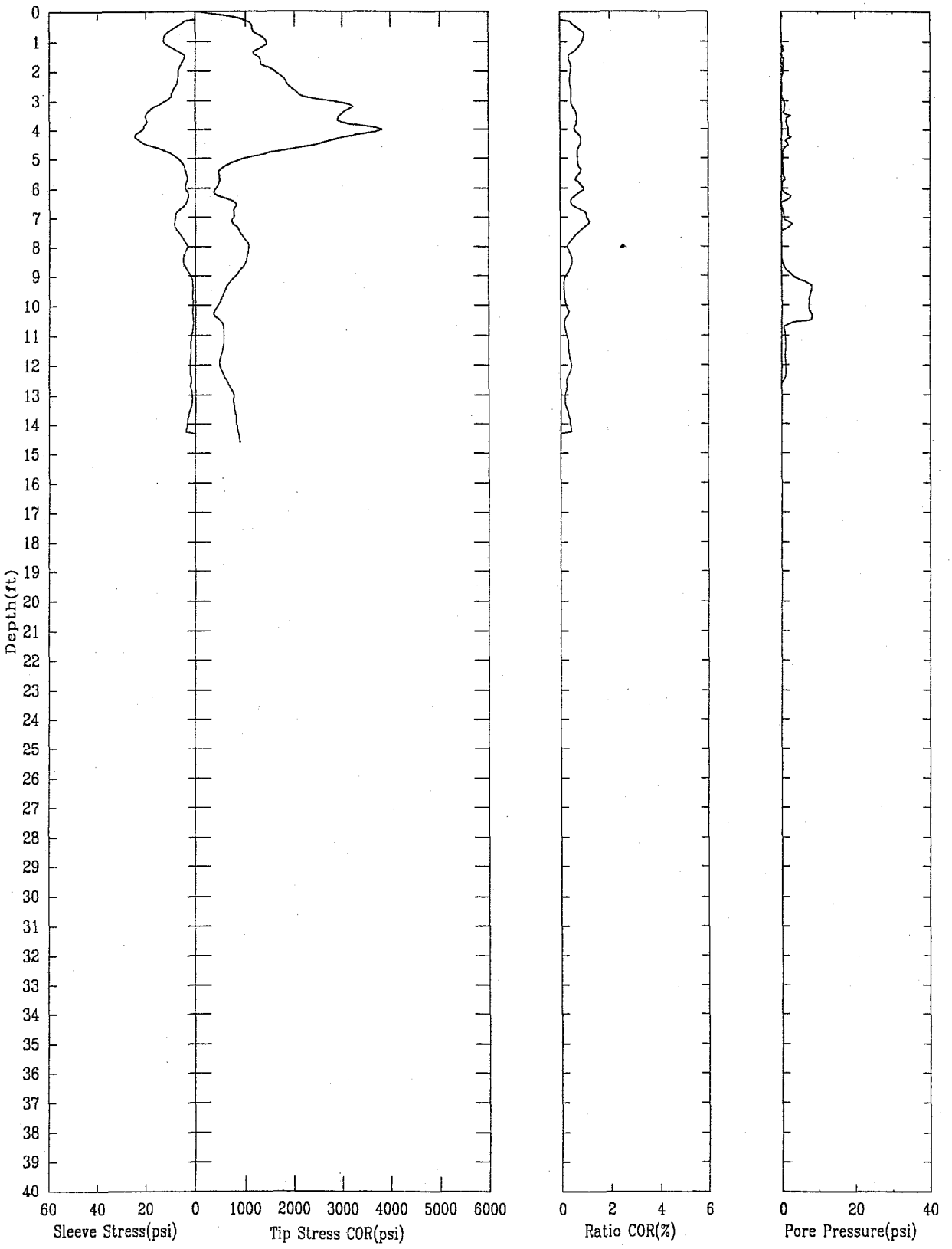


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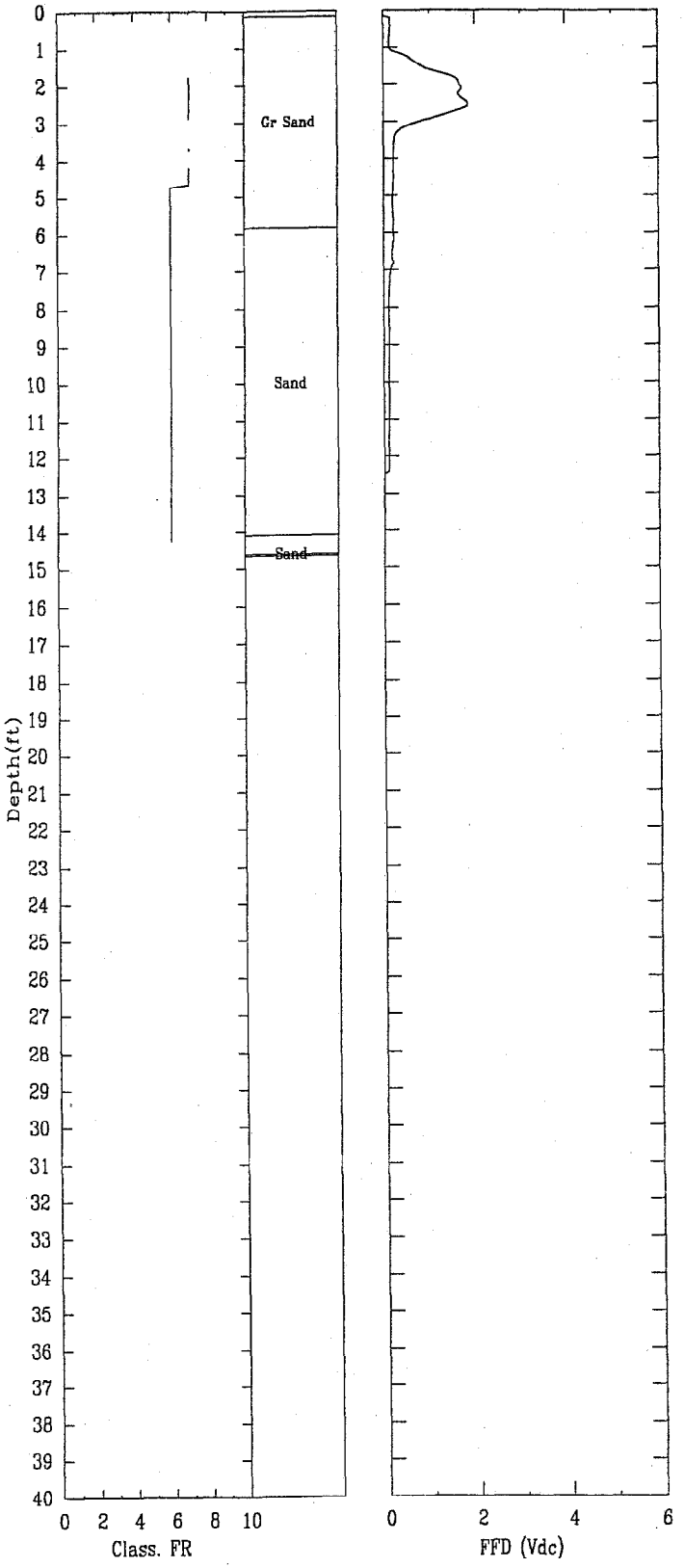


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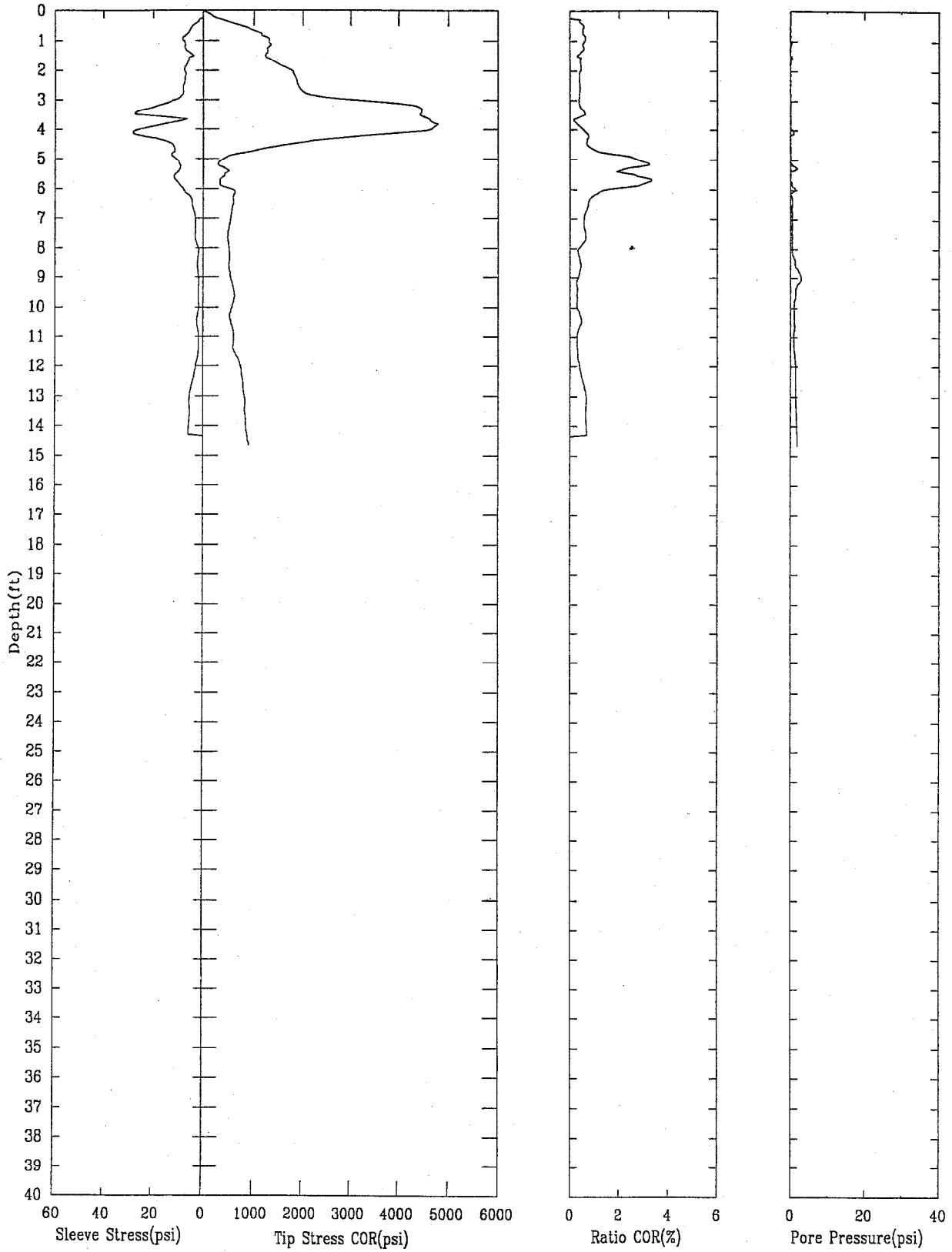


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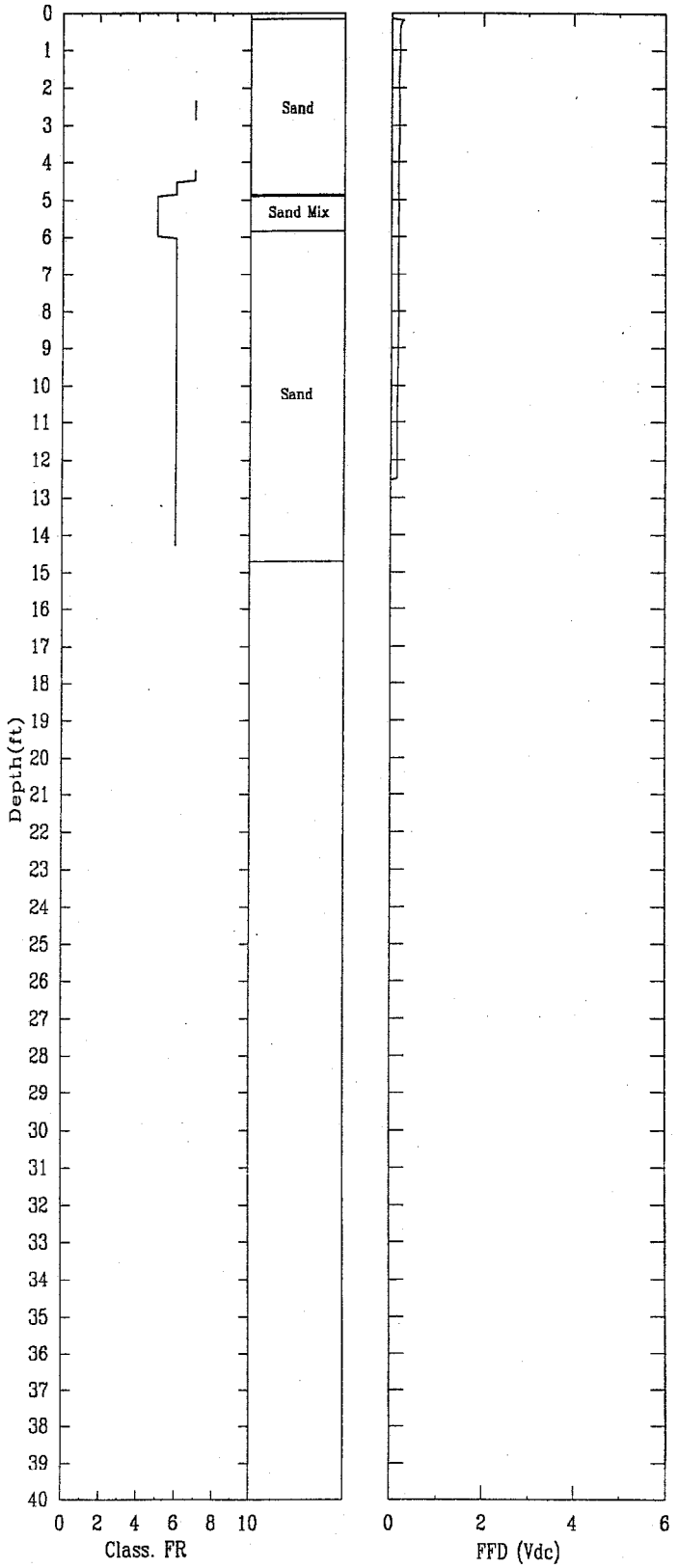


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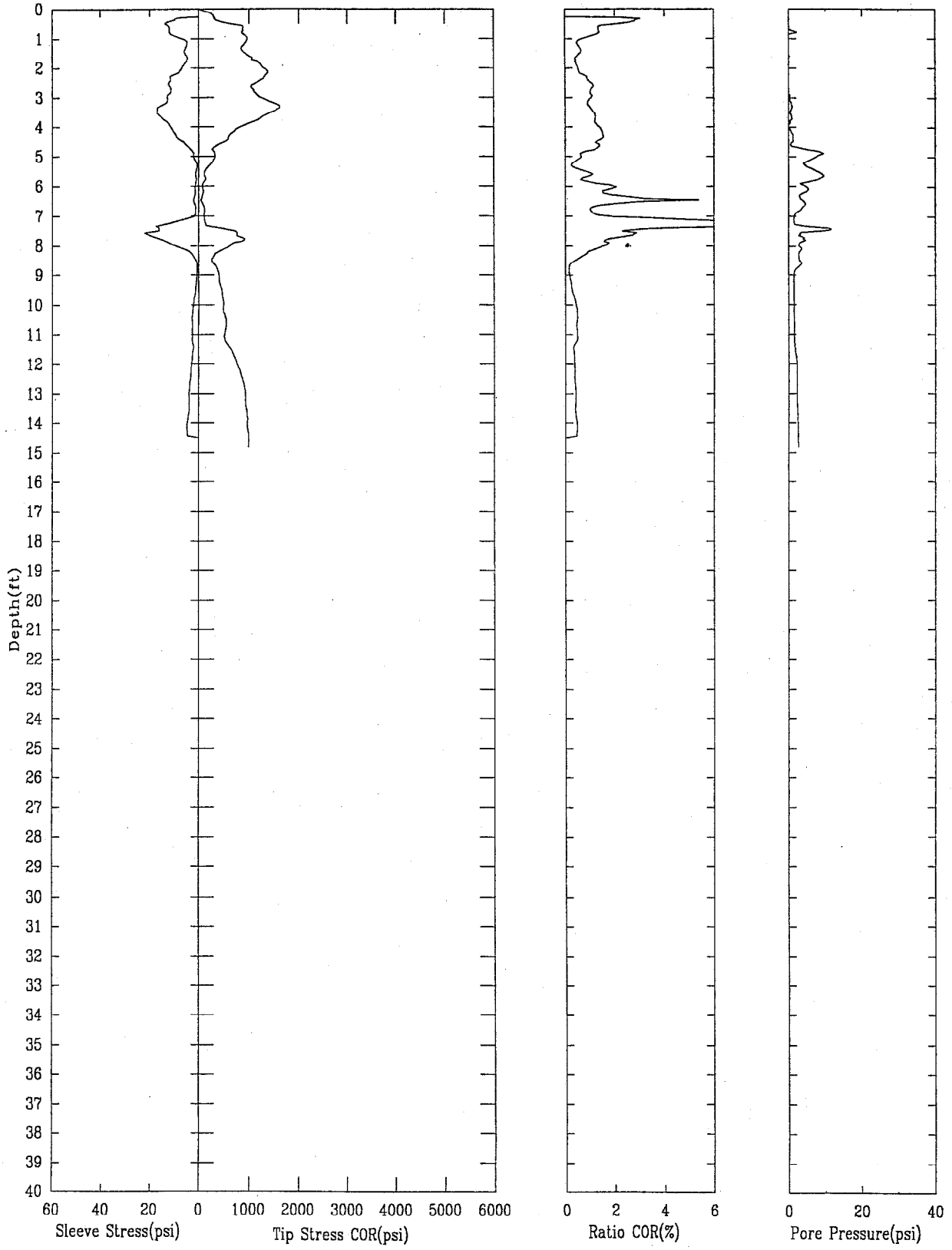


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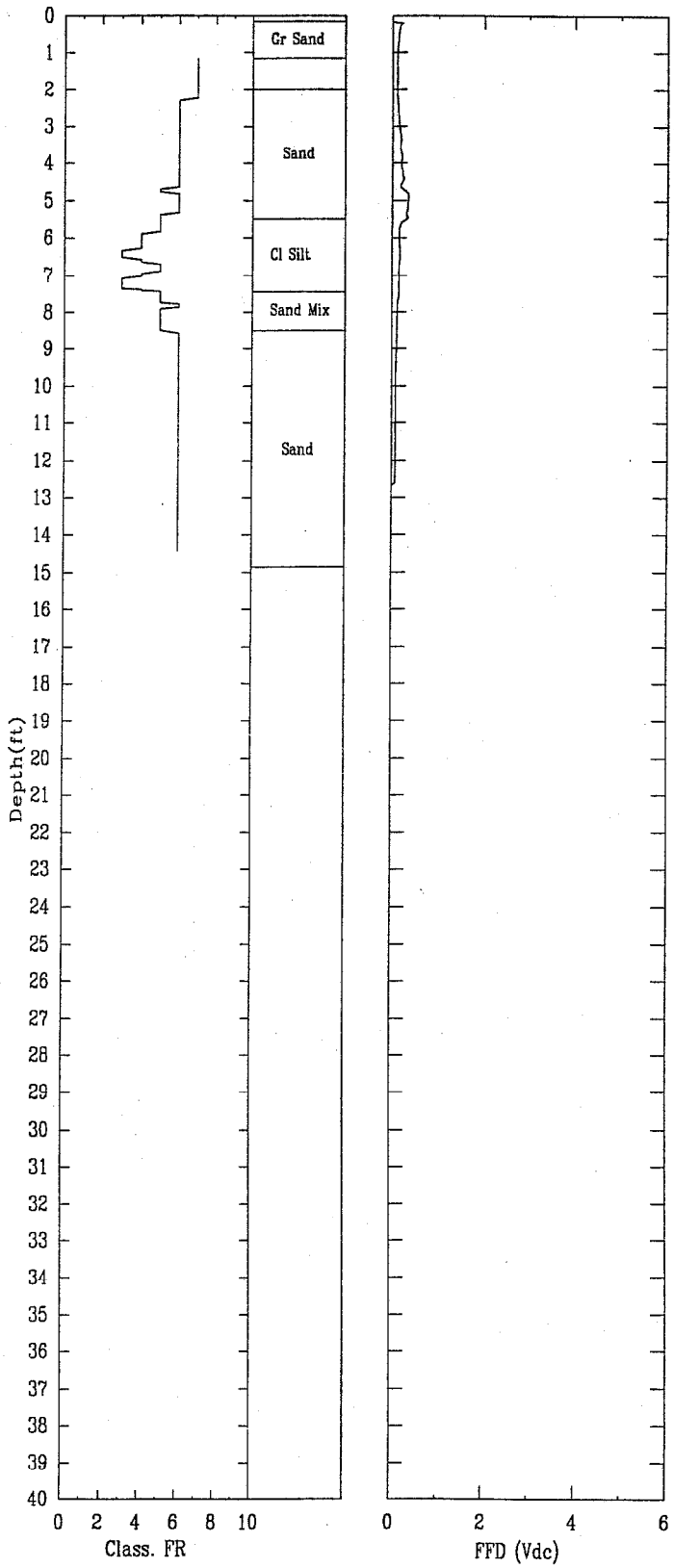


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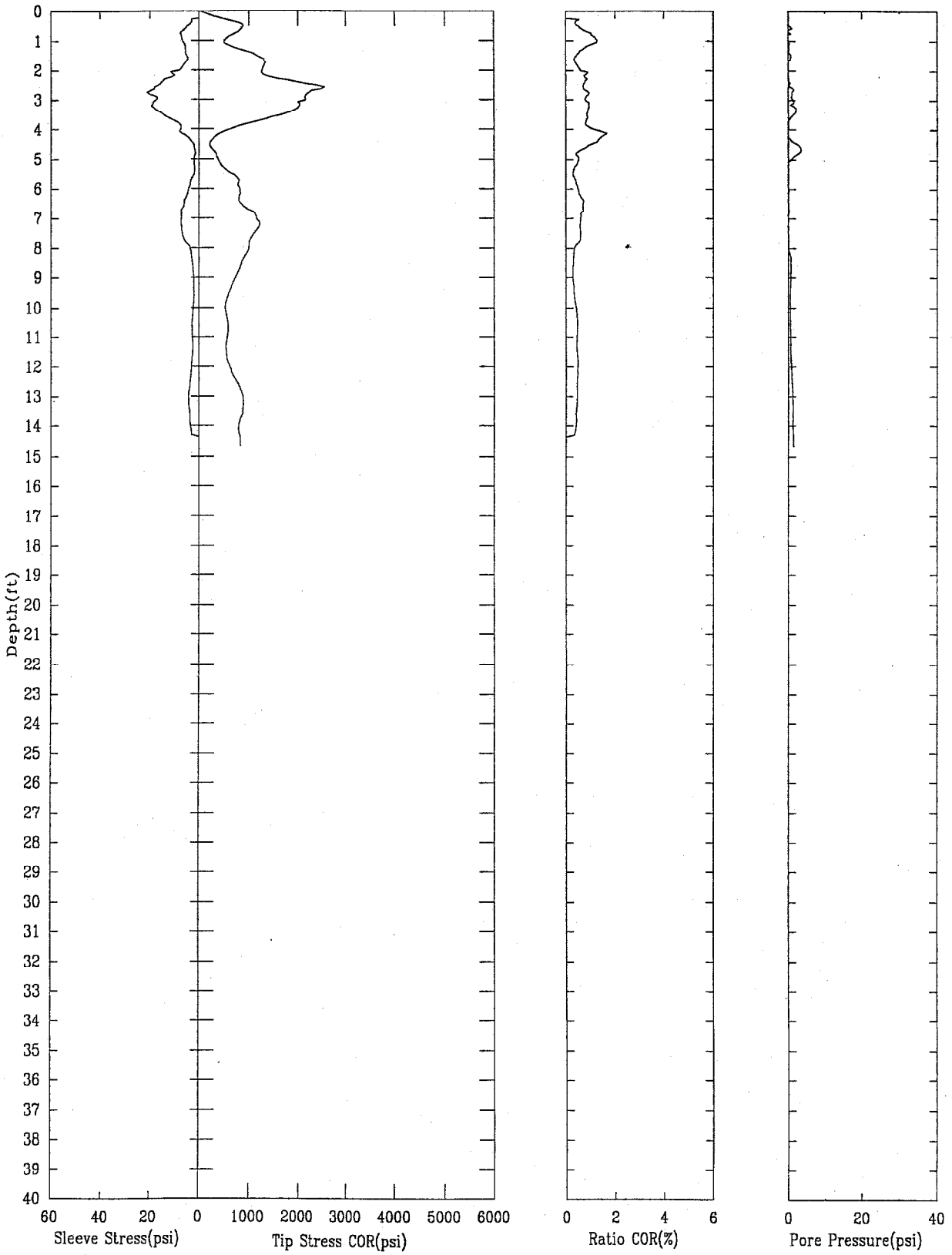


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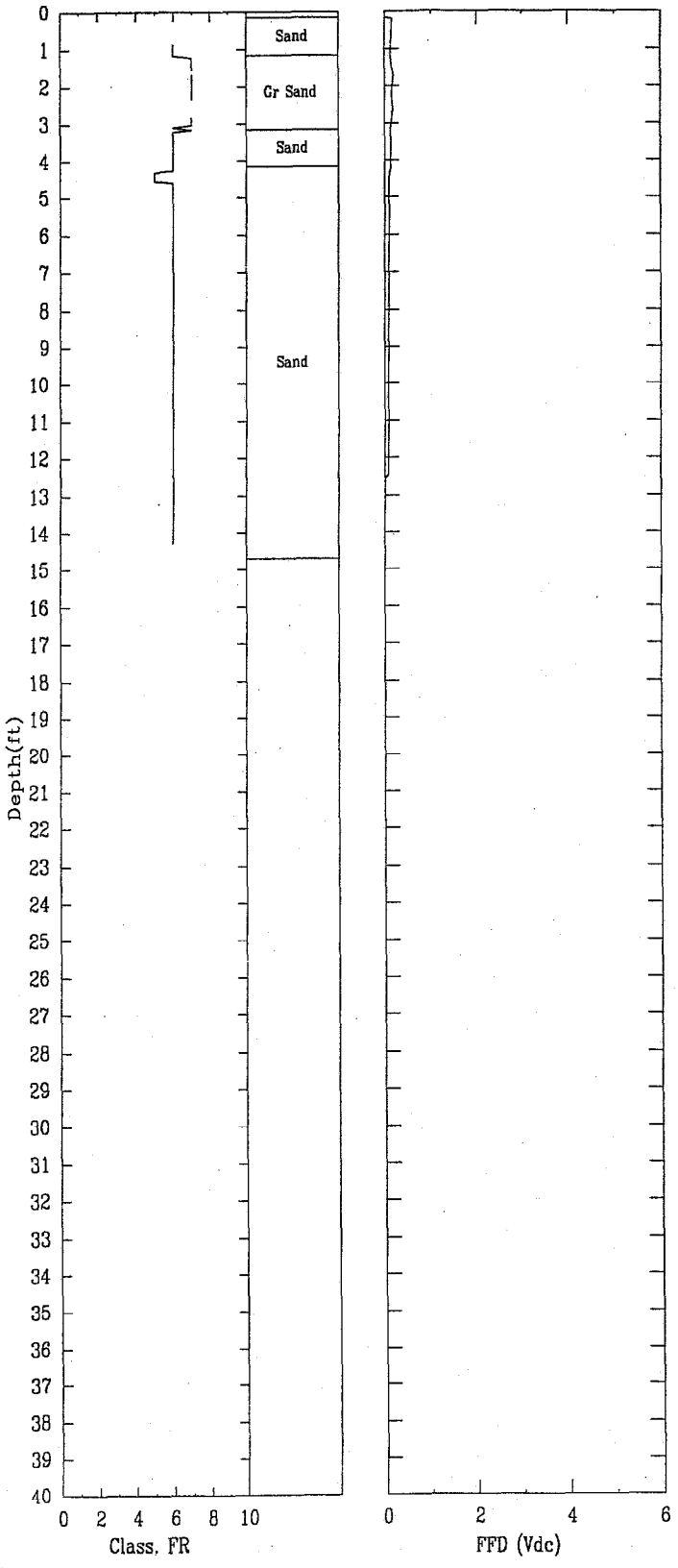


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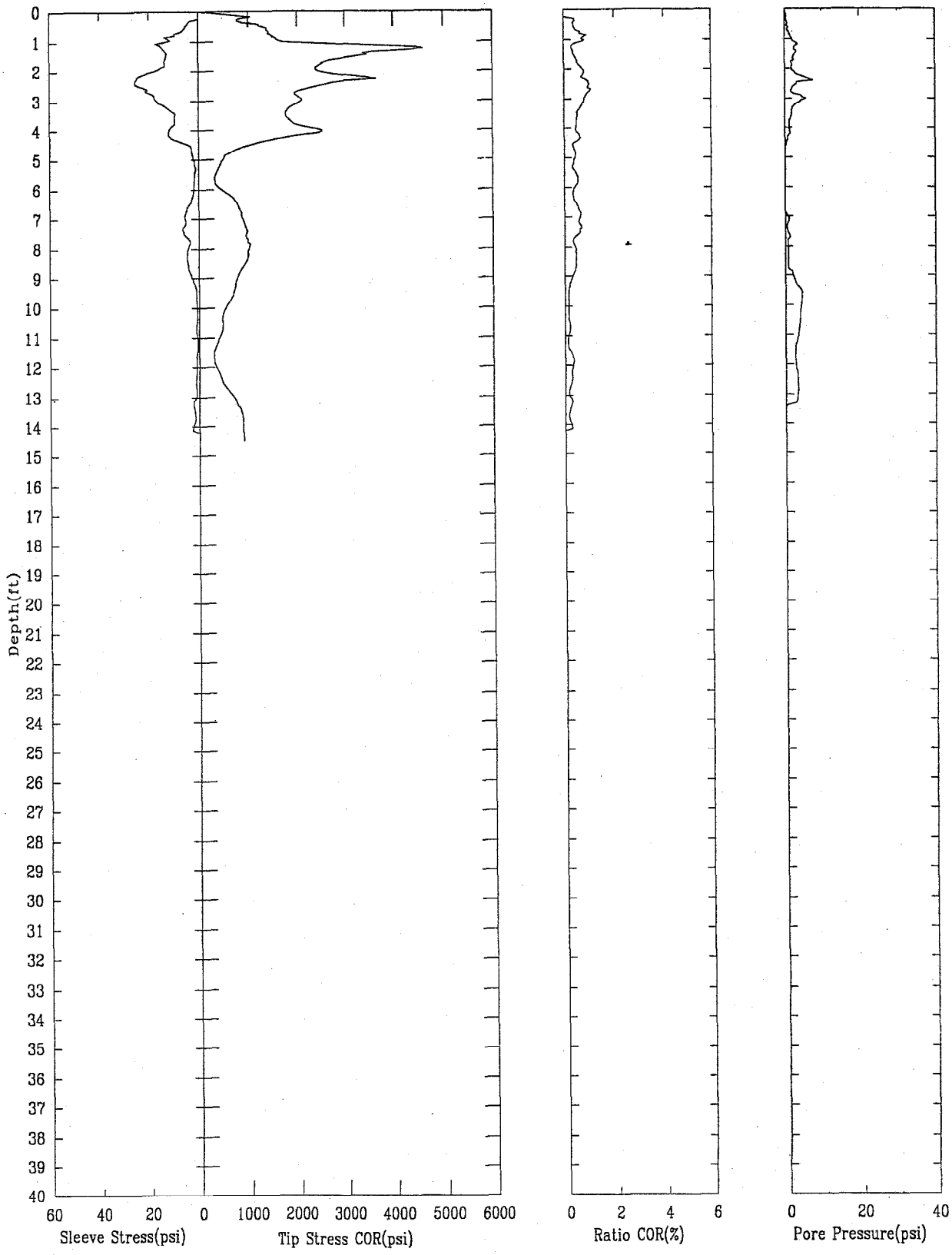


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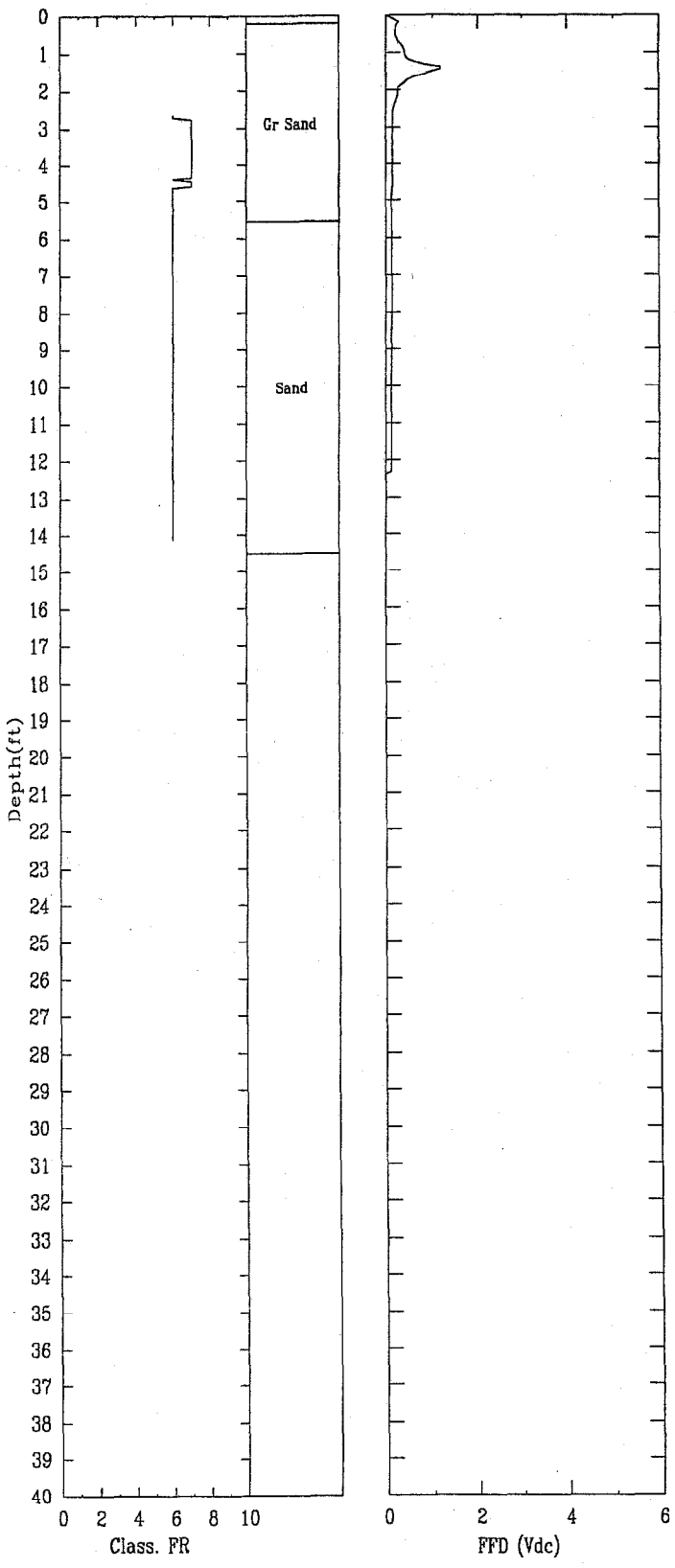


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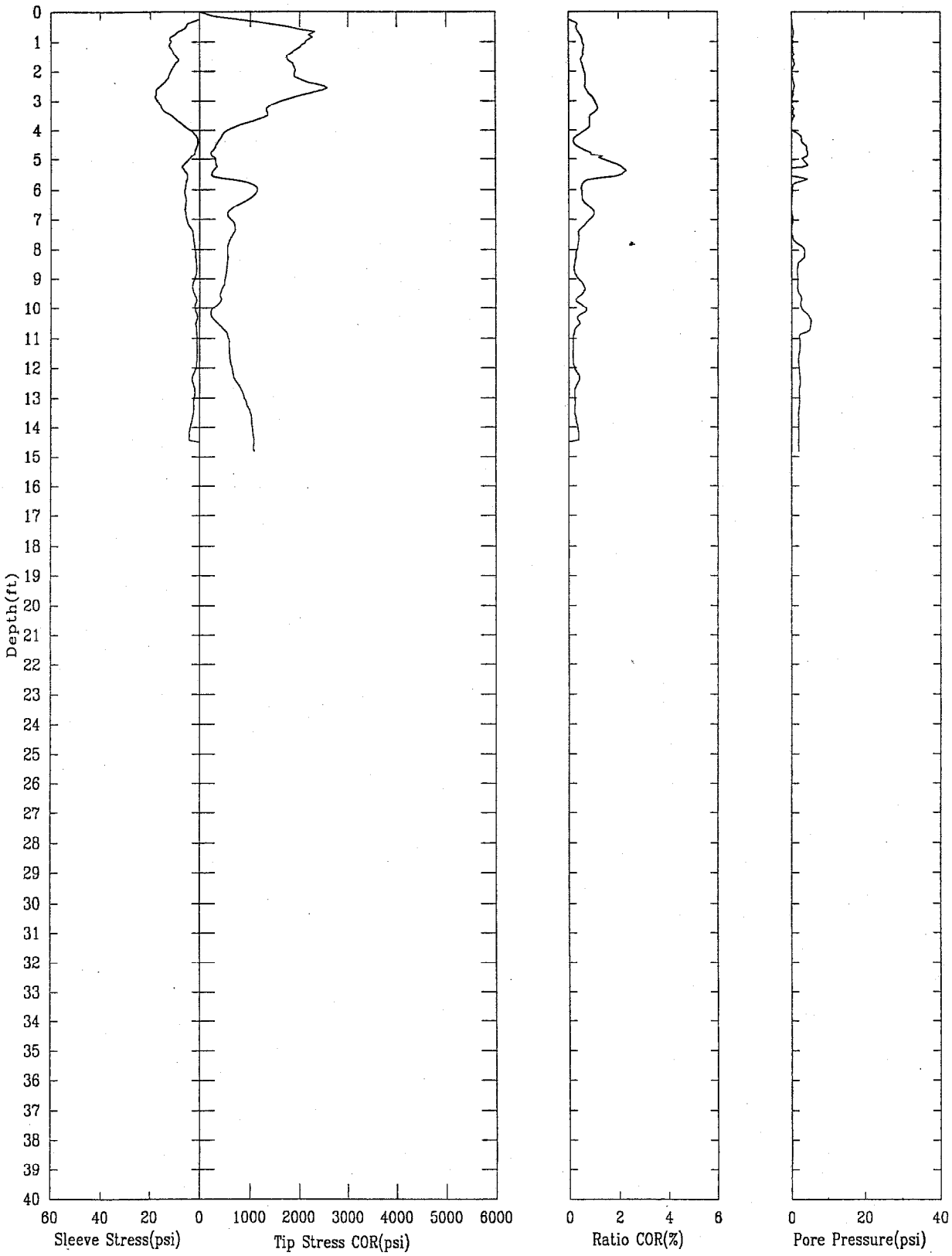


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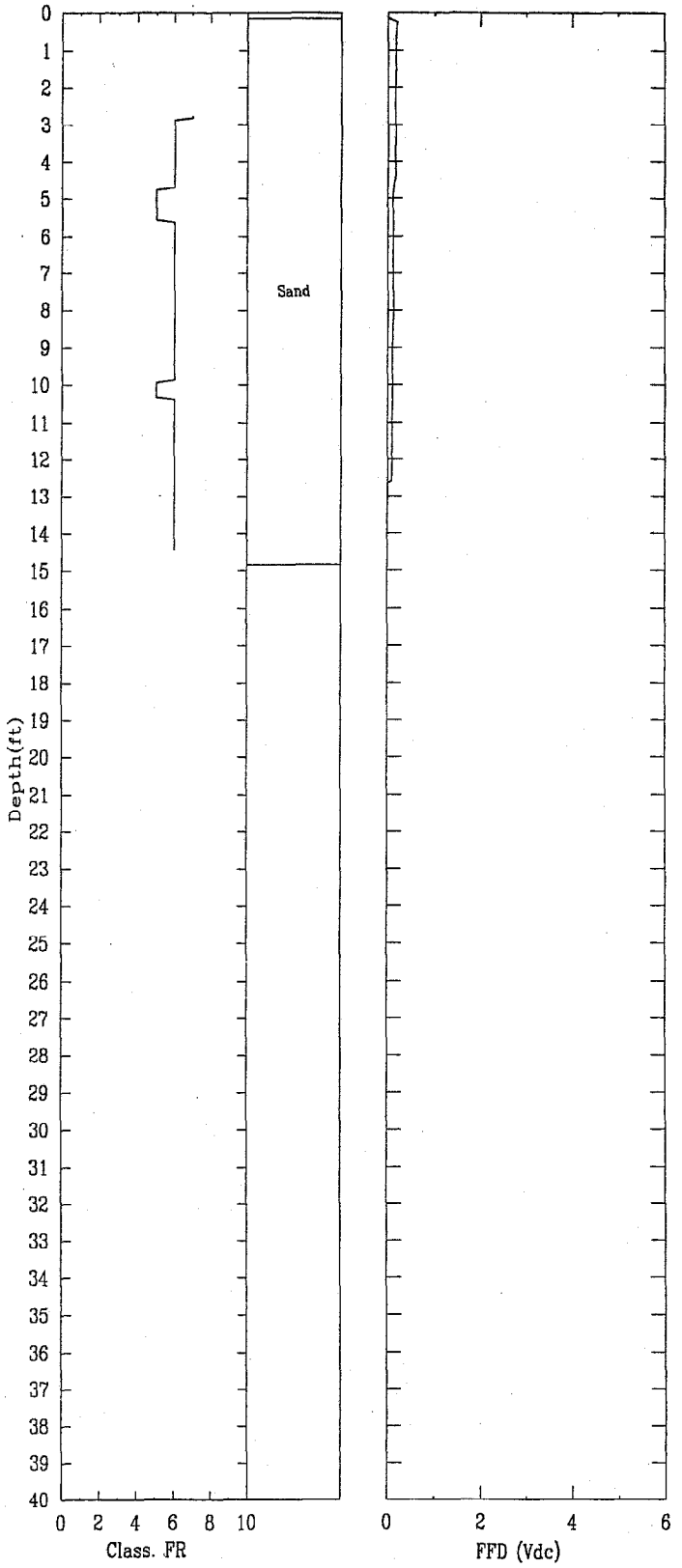


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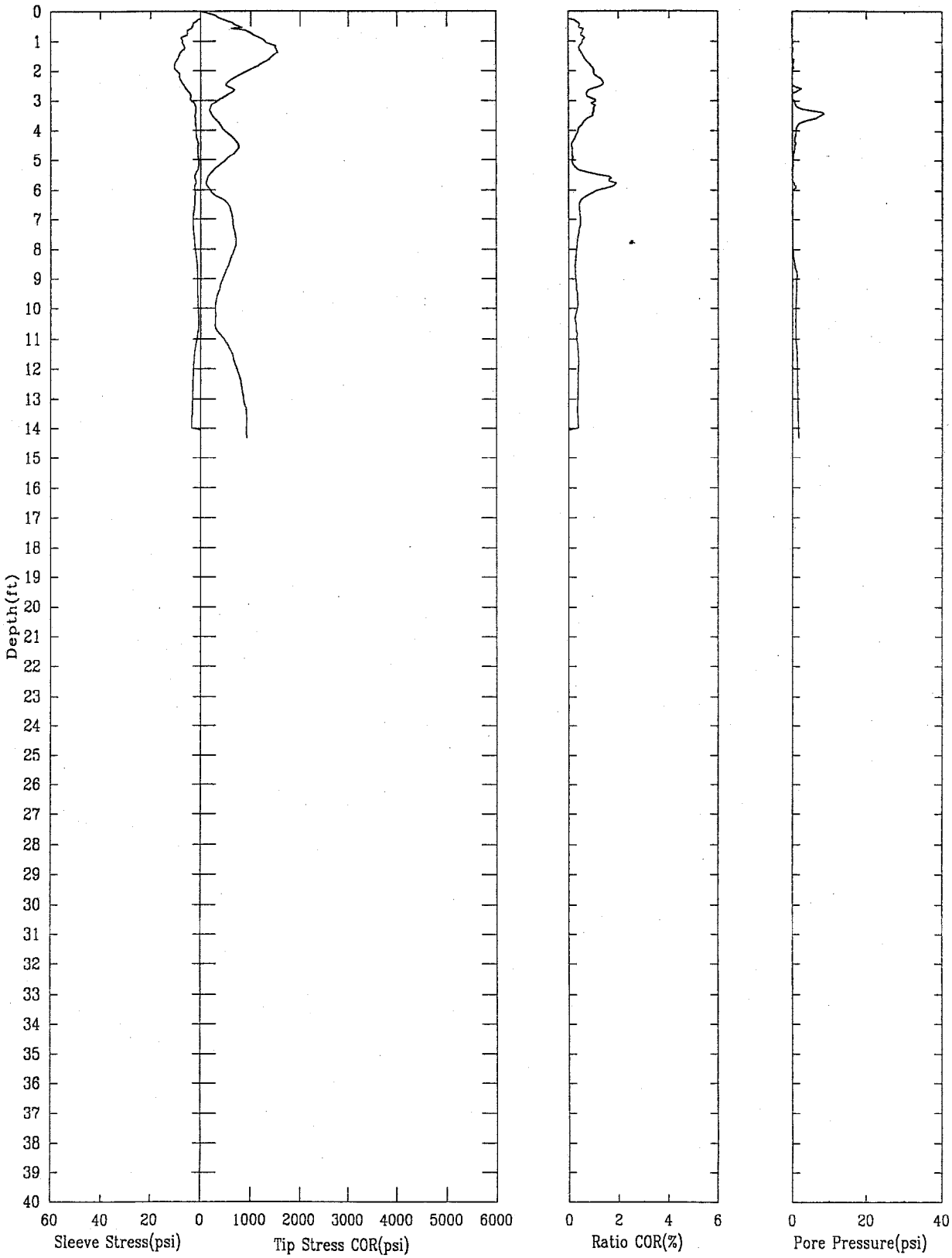


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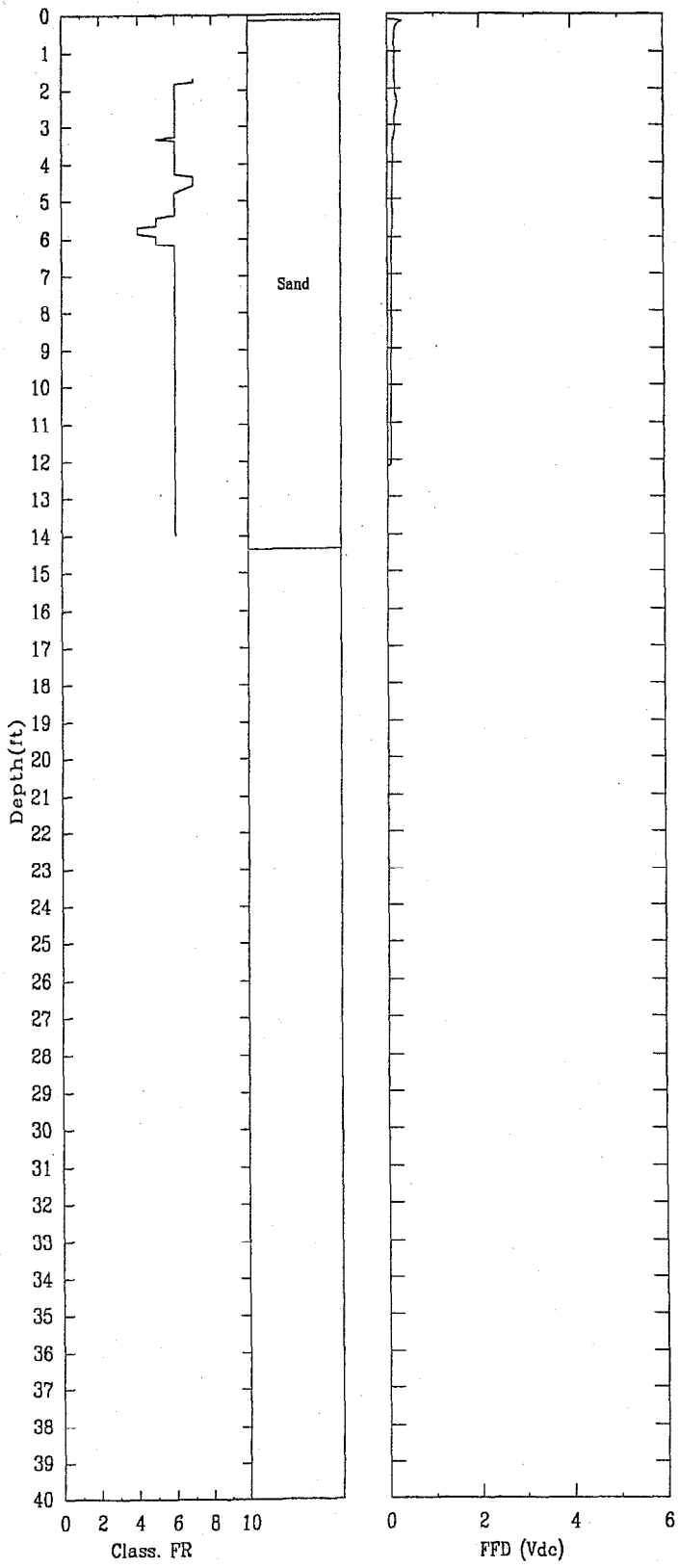


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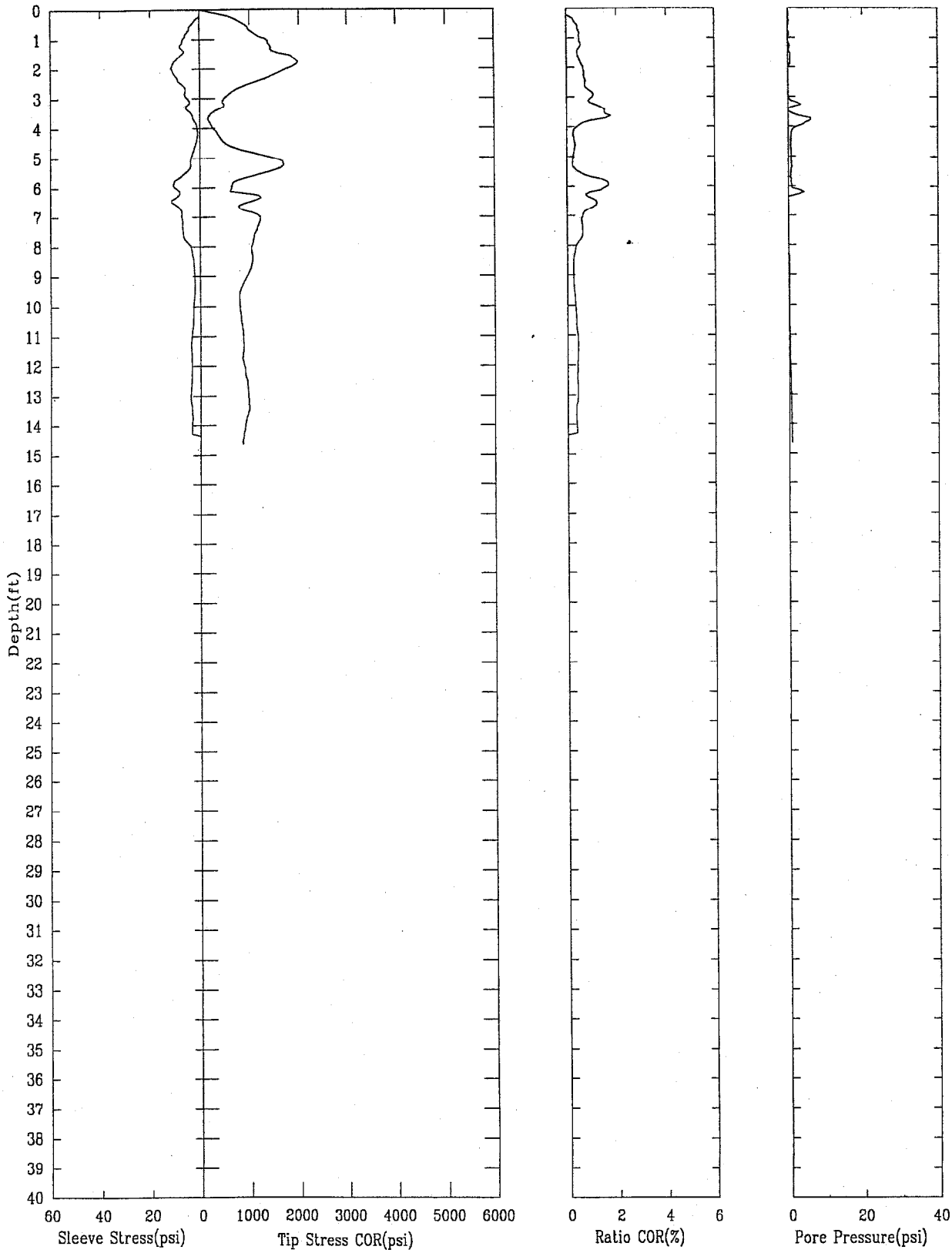


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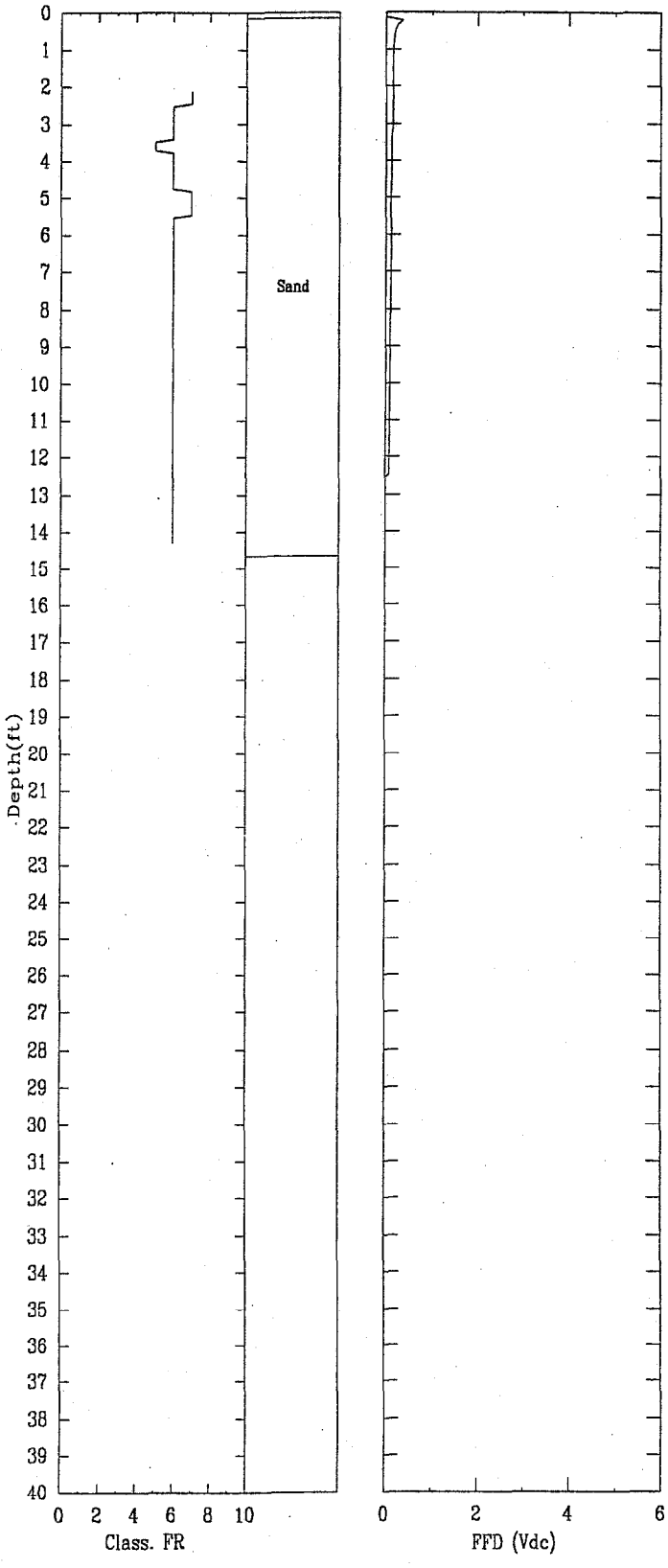


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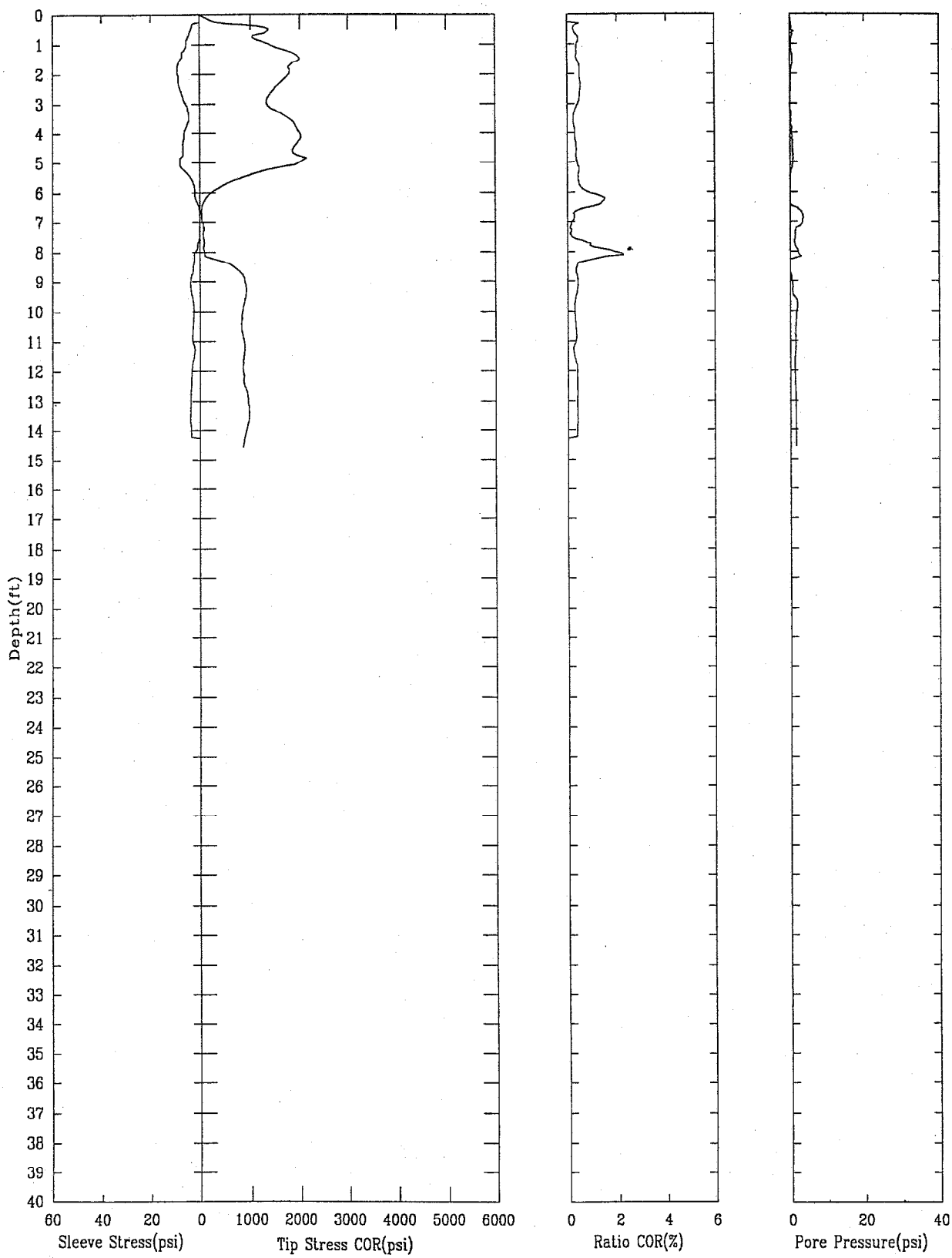


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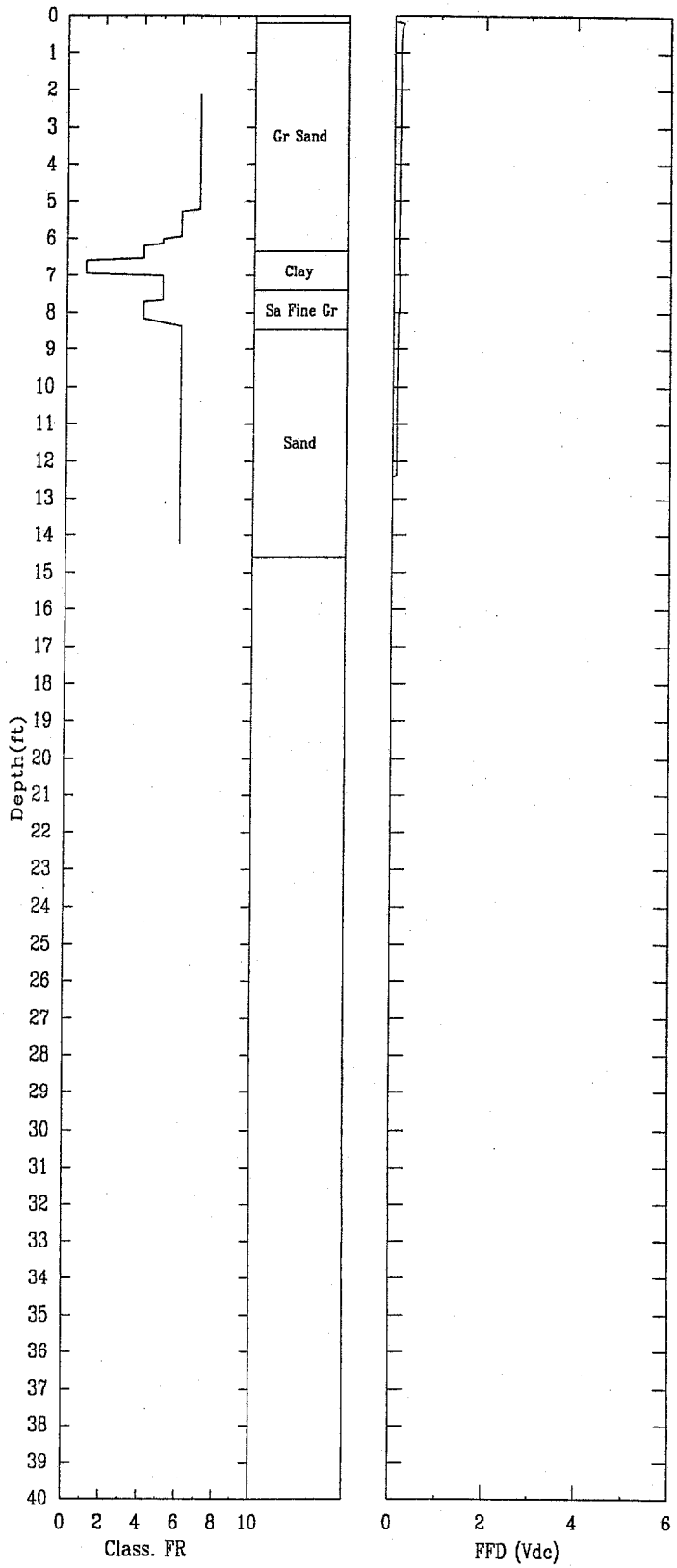


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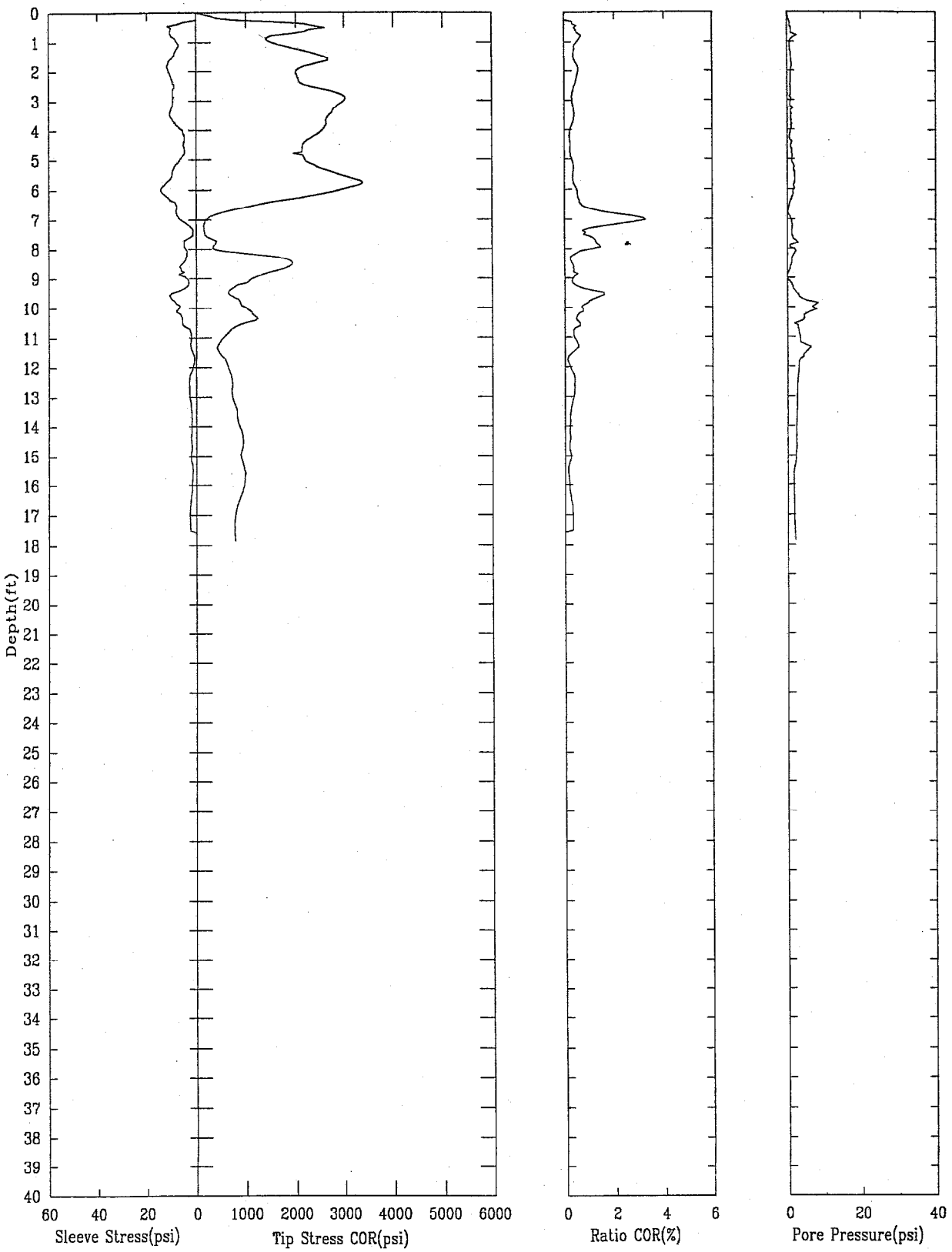


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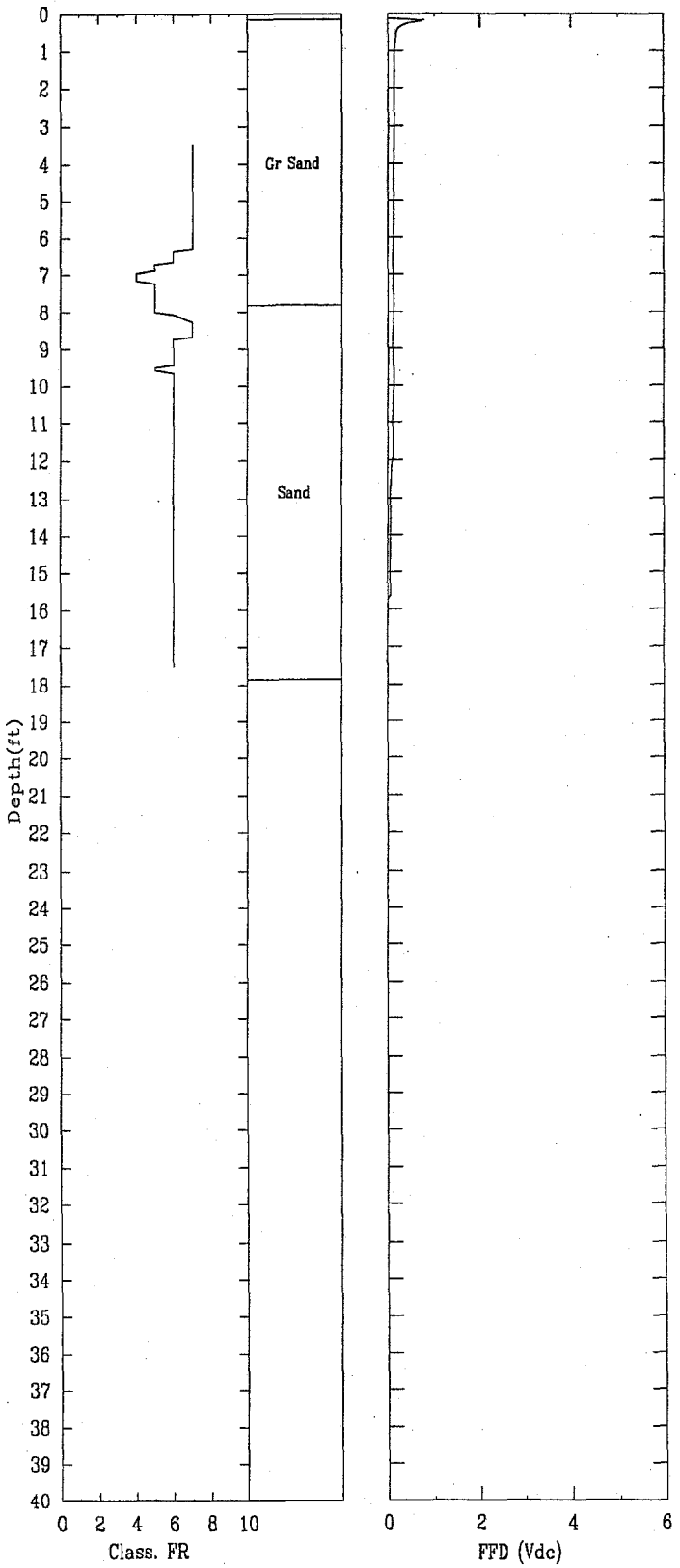


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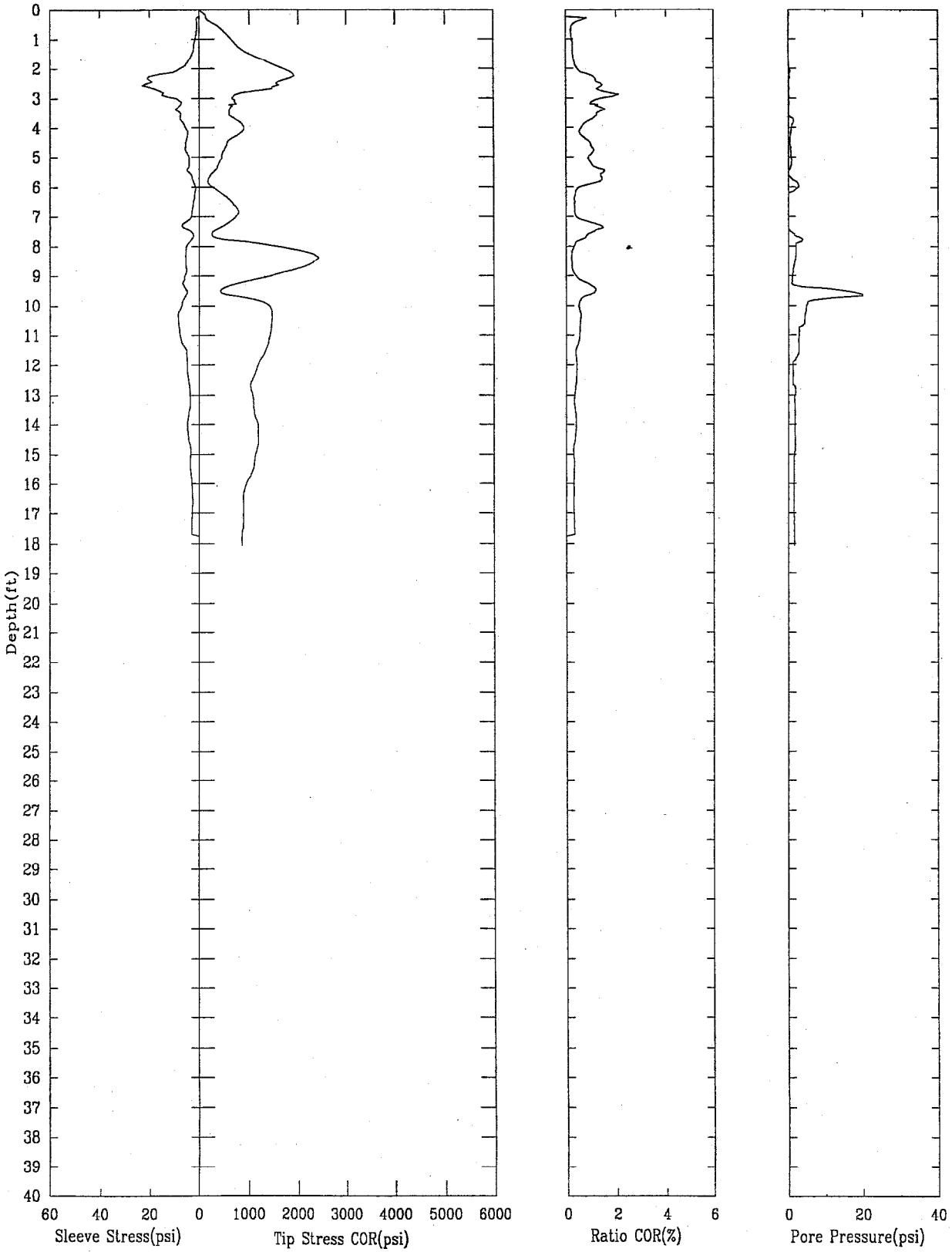


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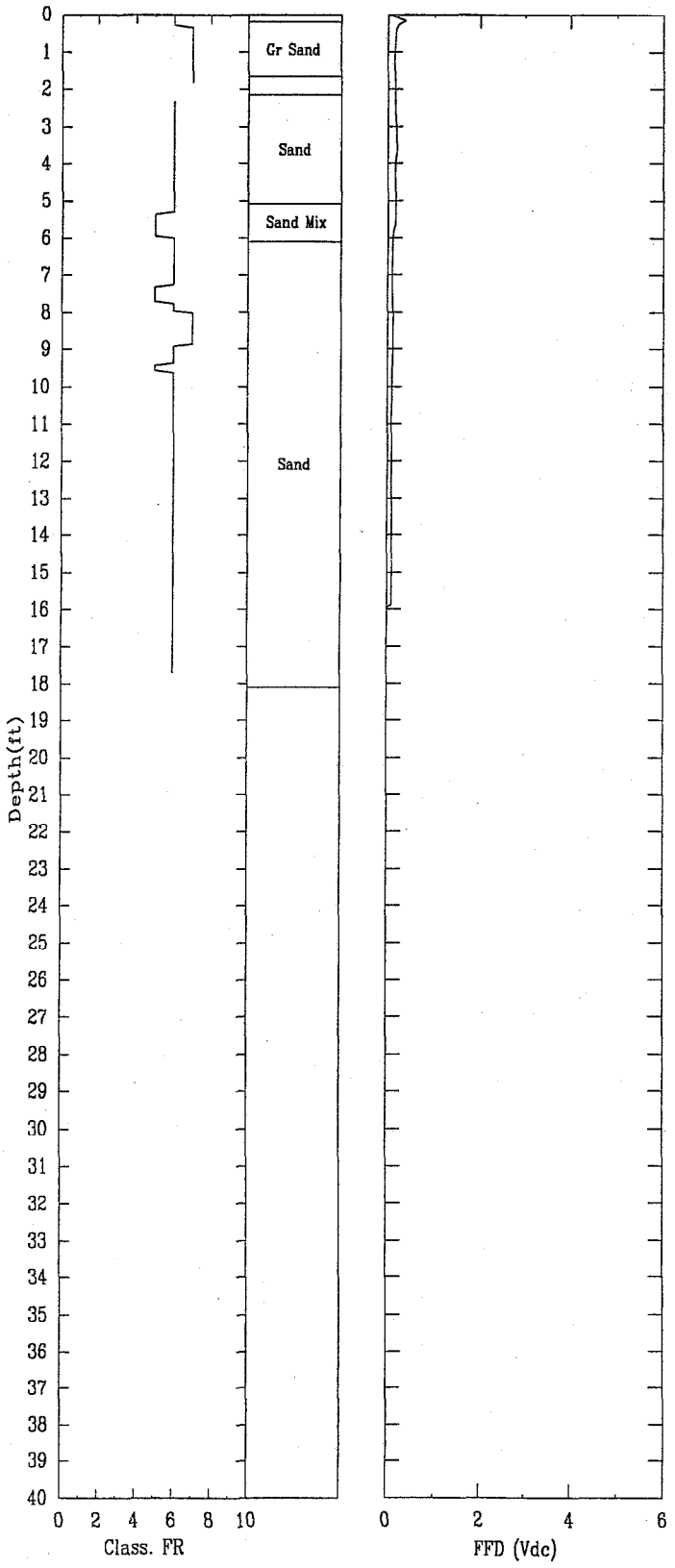


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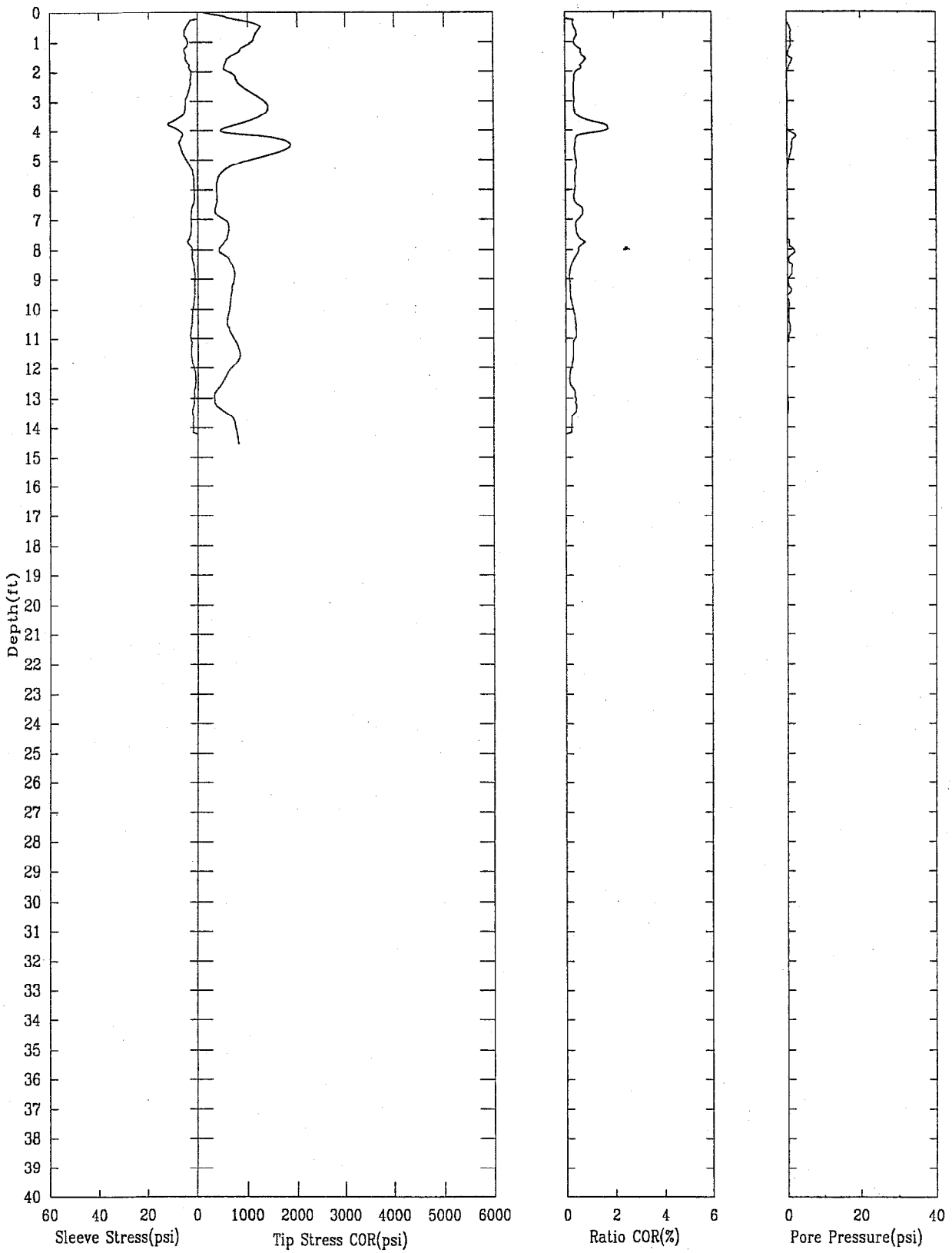


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16CPT-20 APPLIED RESEARCH ASSOCIATES, INC. 10/10/96

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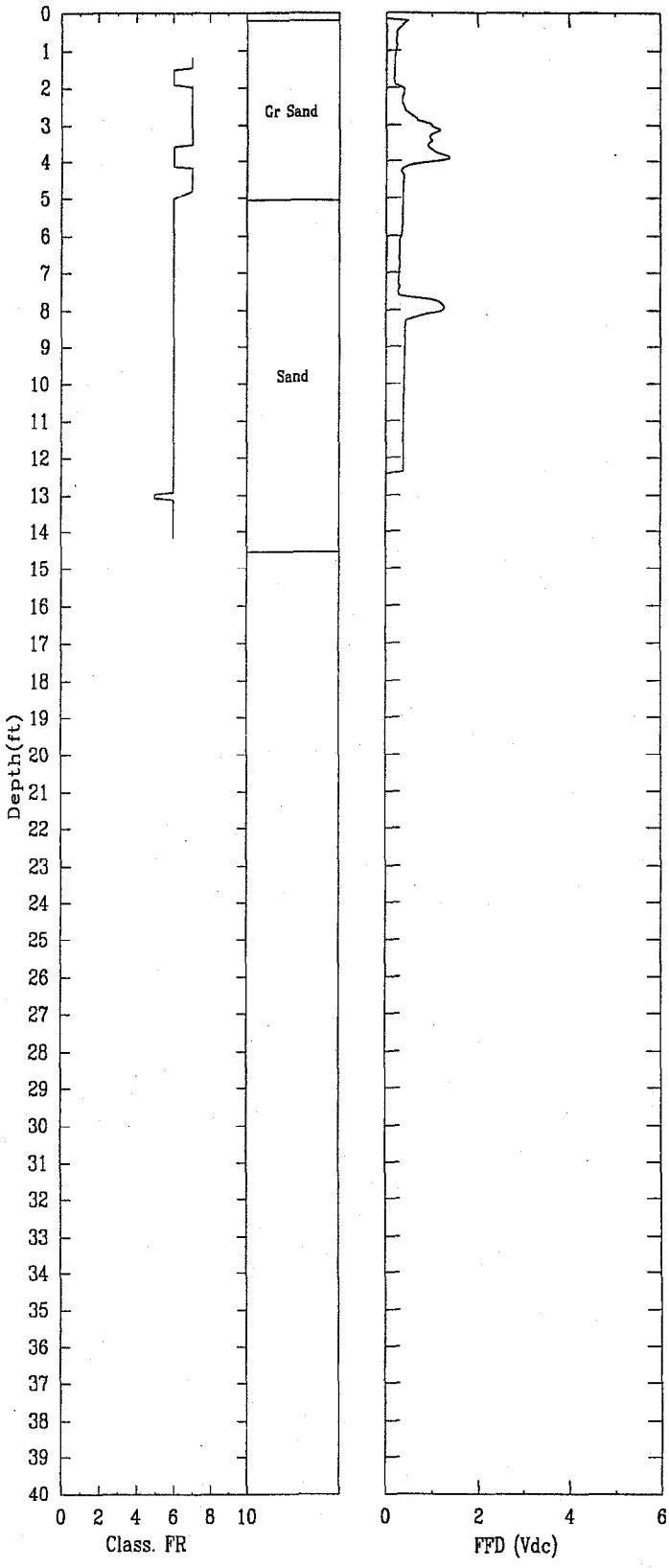


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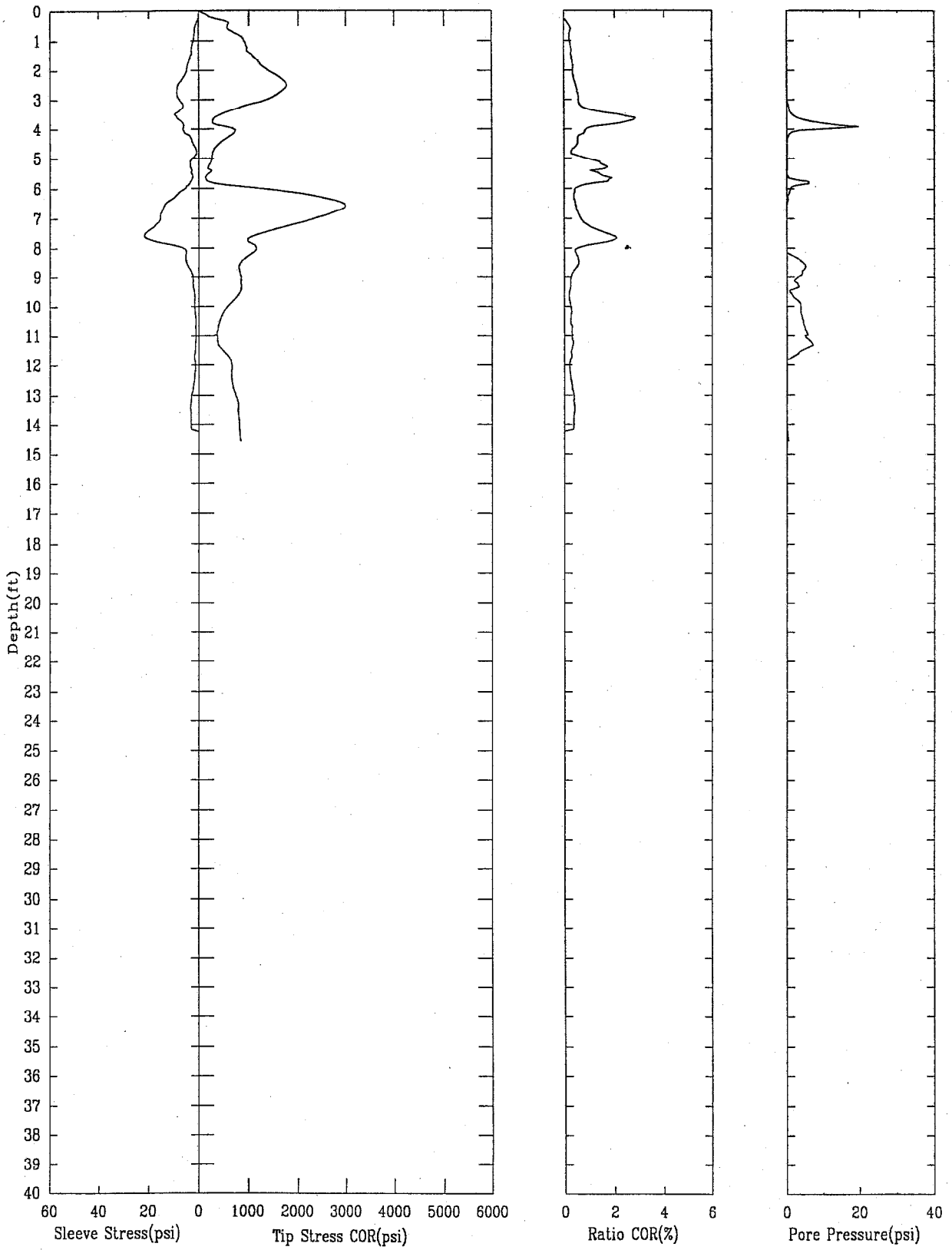


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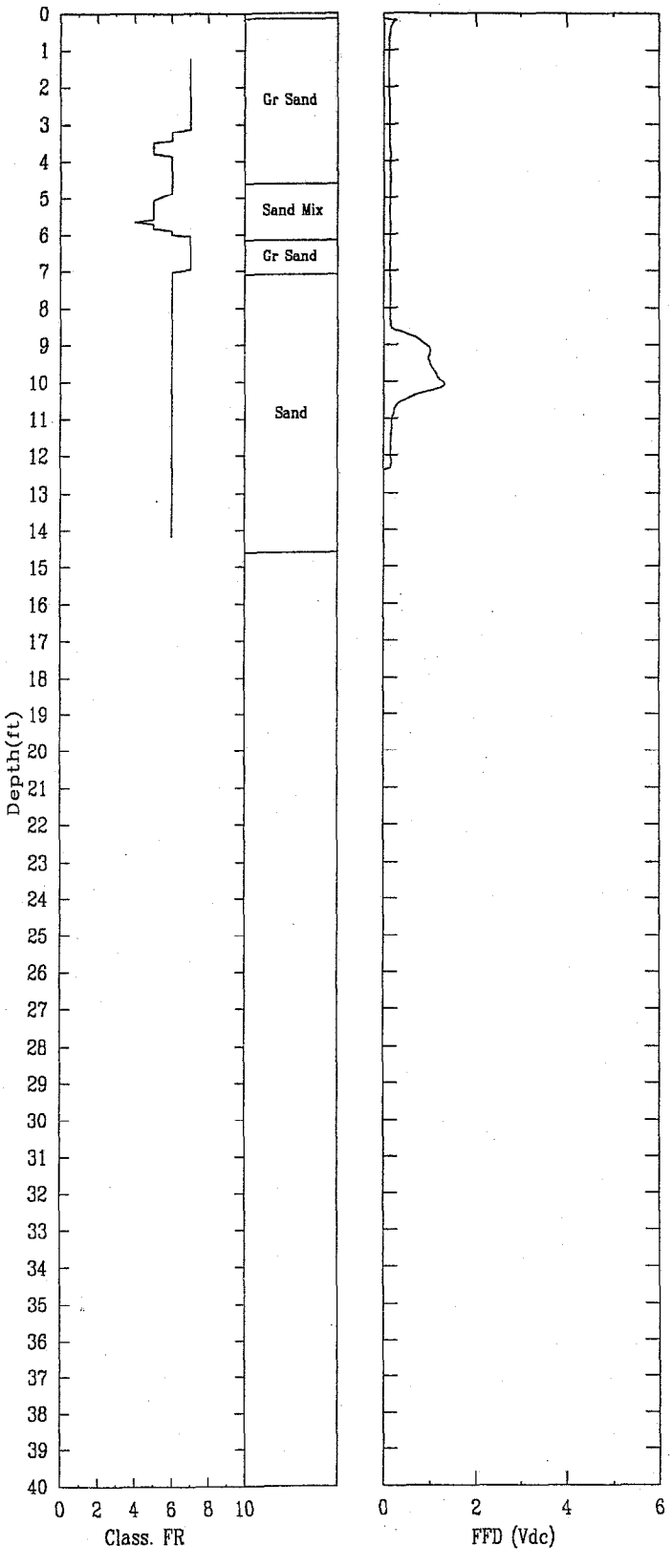


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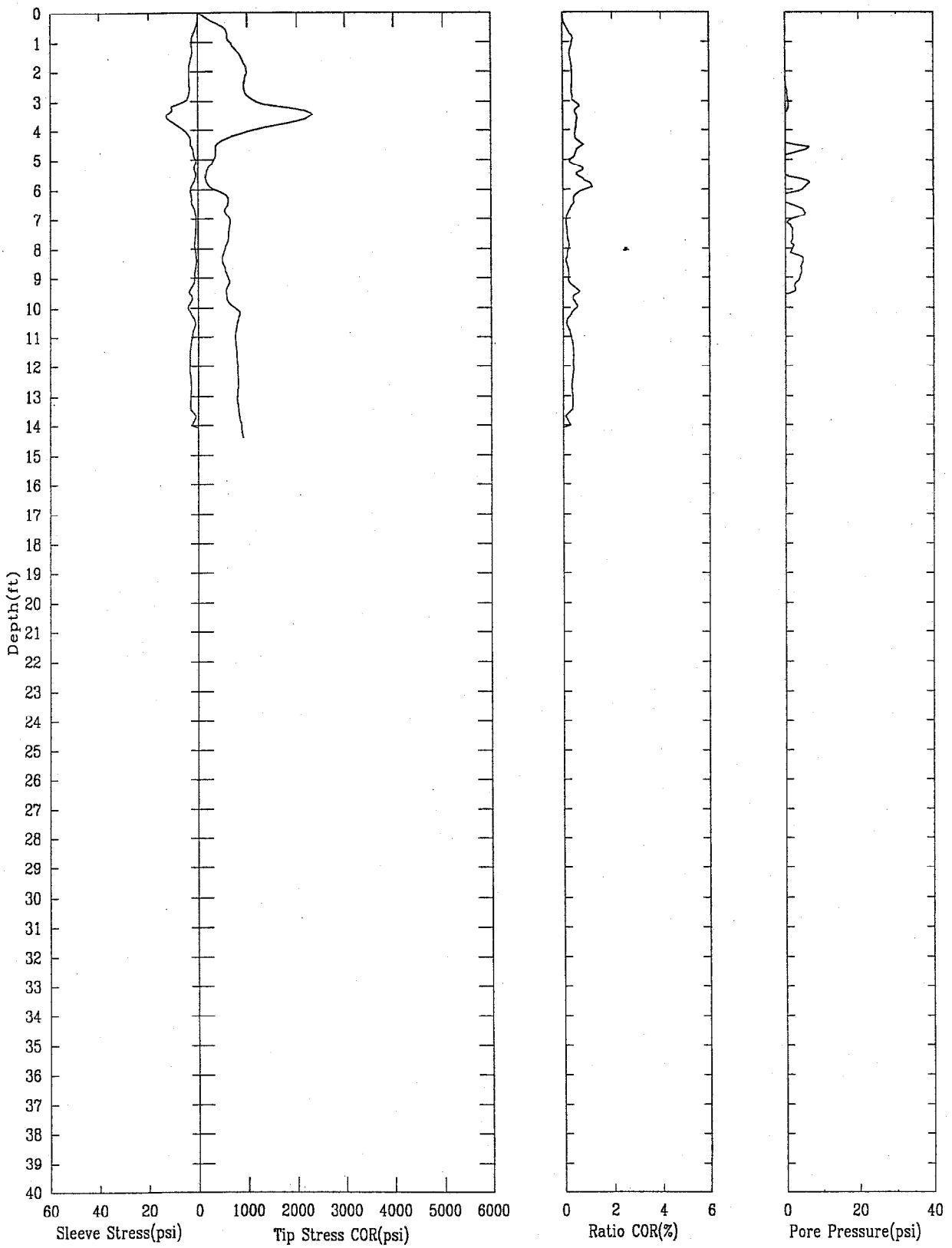


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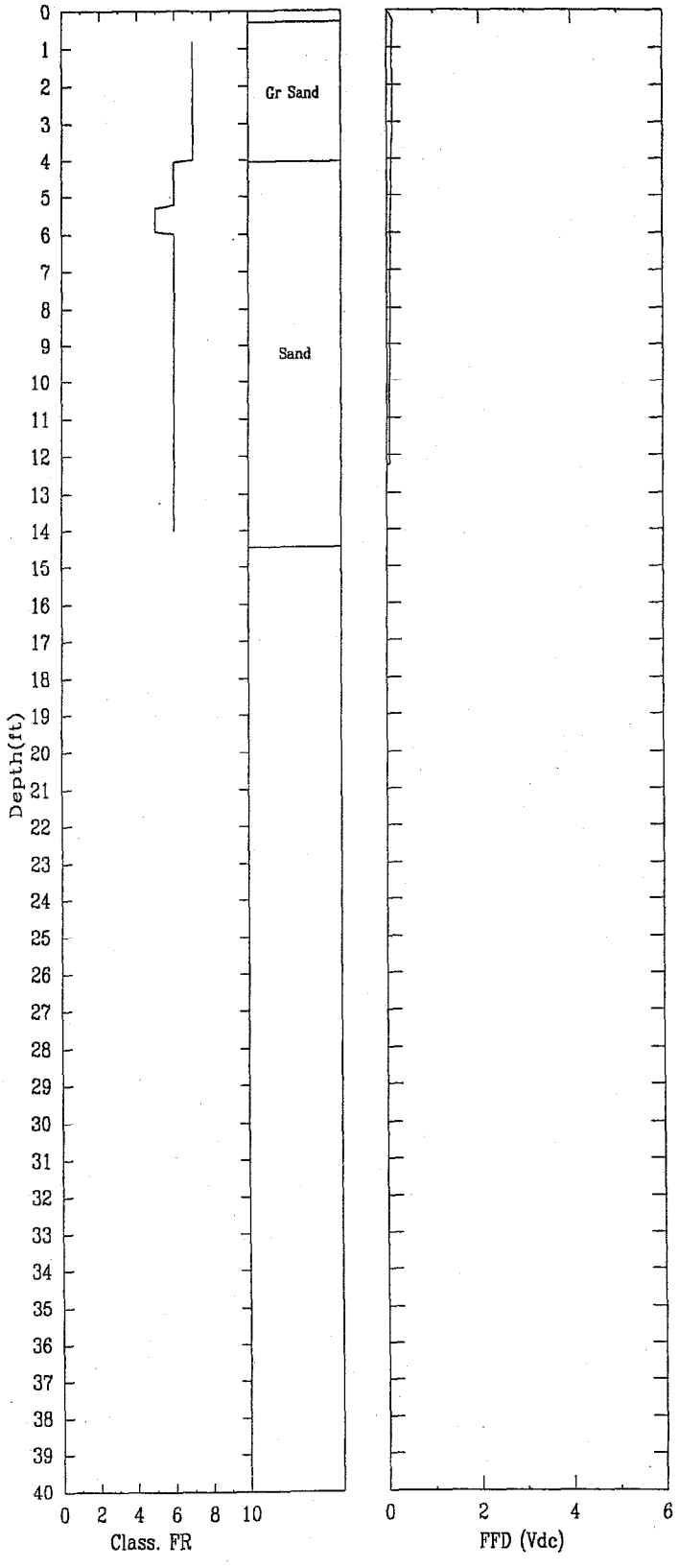


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16CPT-23 APPLIED RESEARCH ASSOCIATES, INC. 10/10/96

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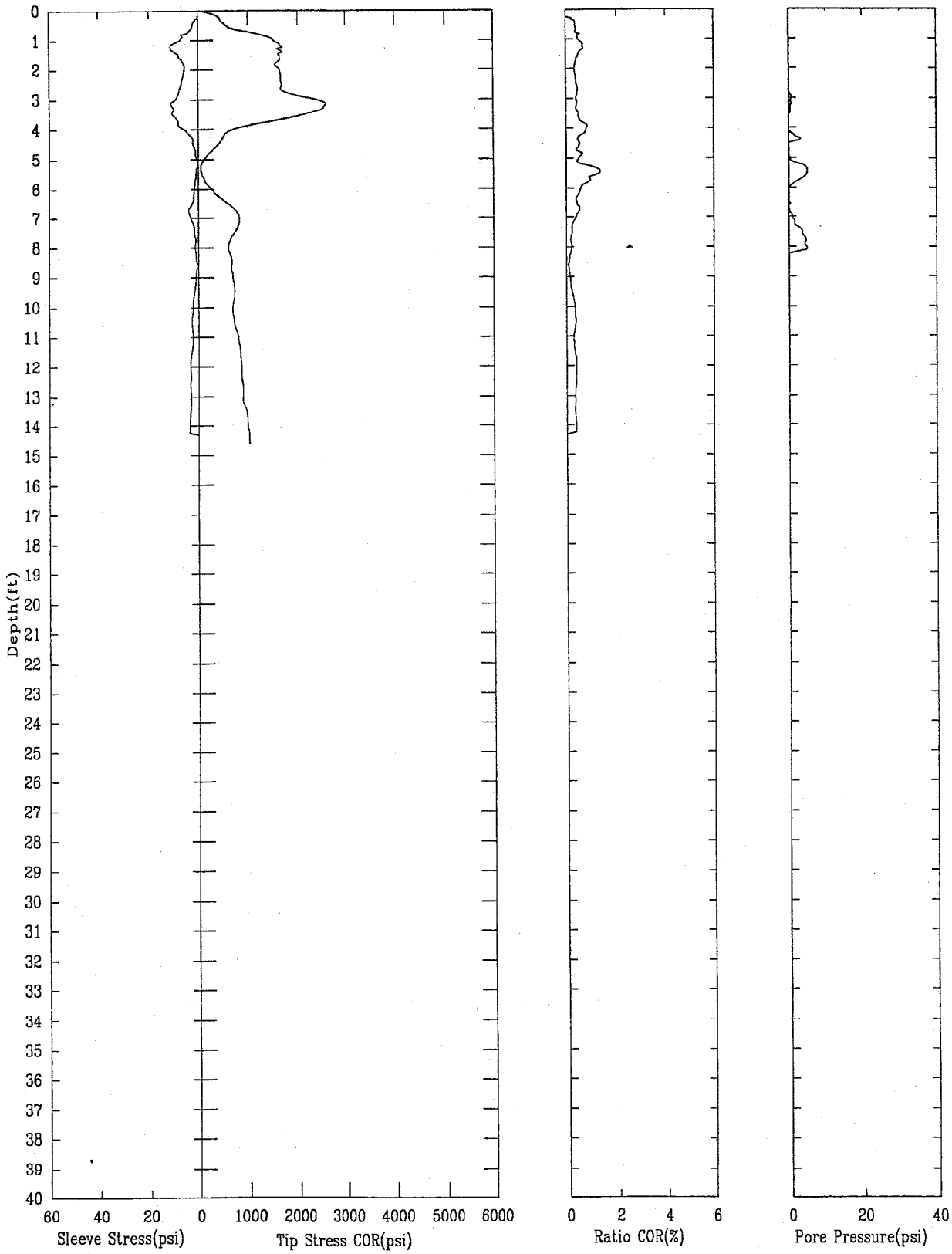


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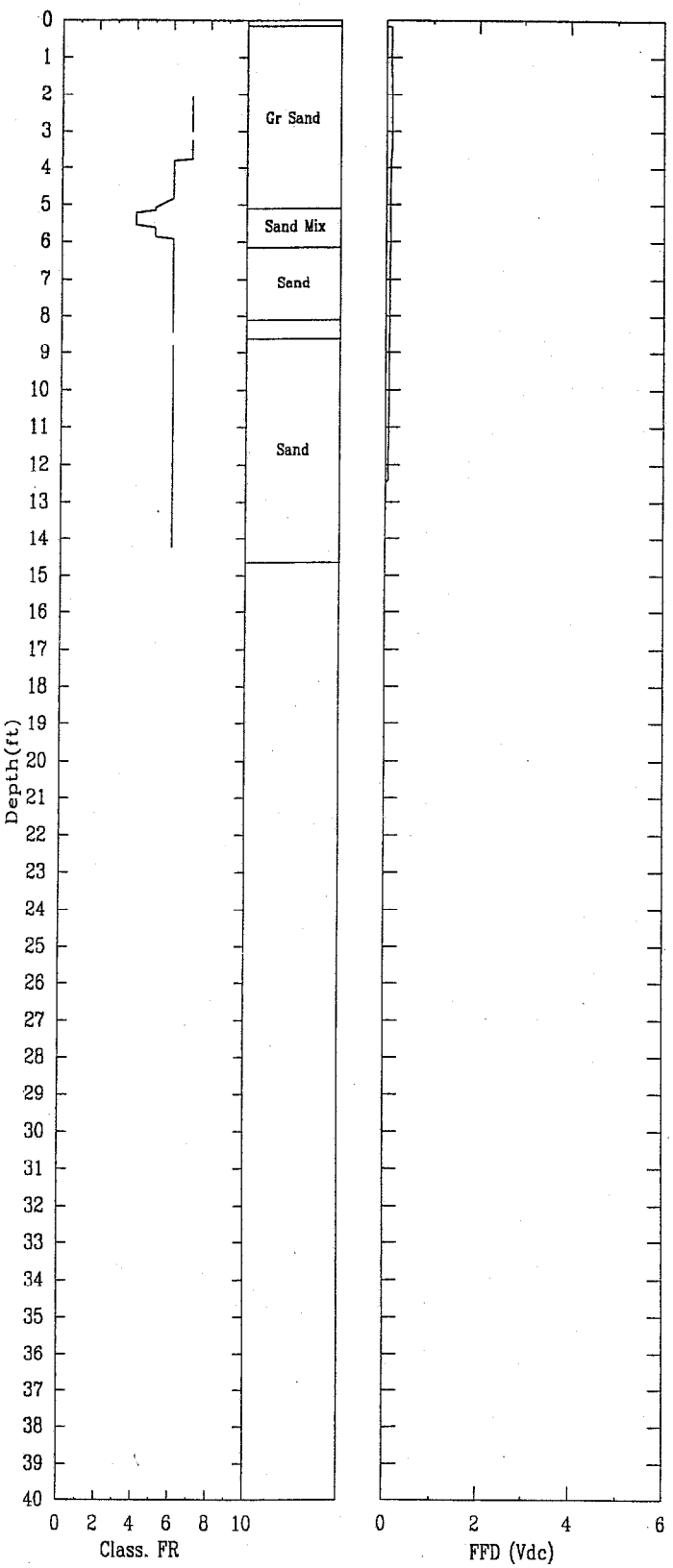


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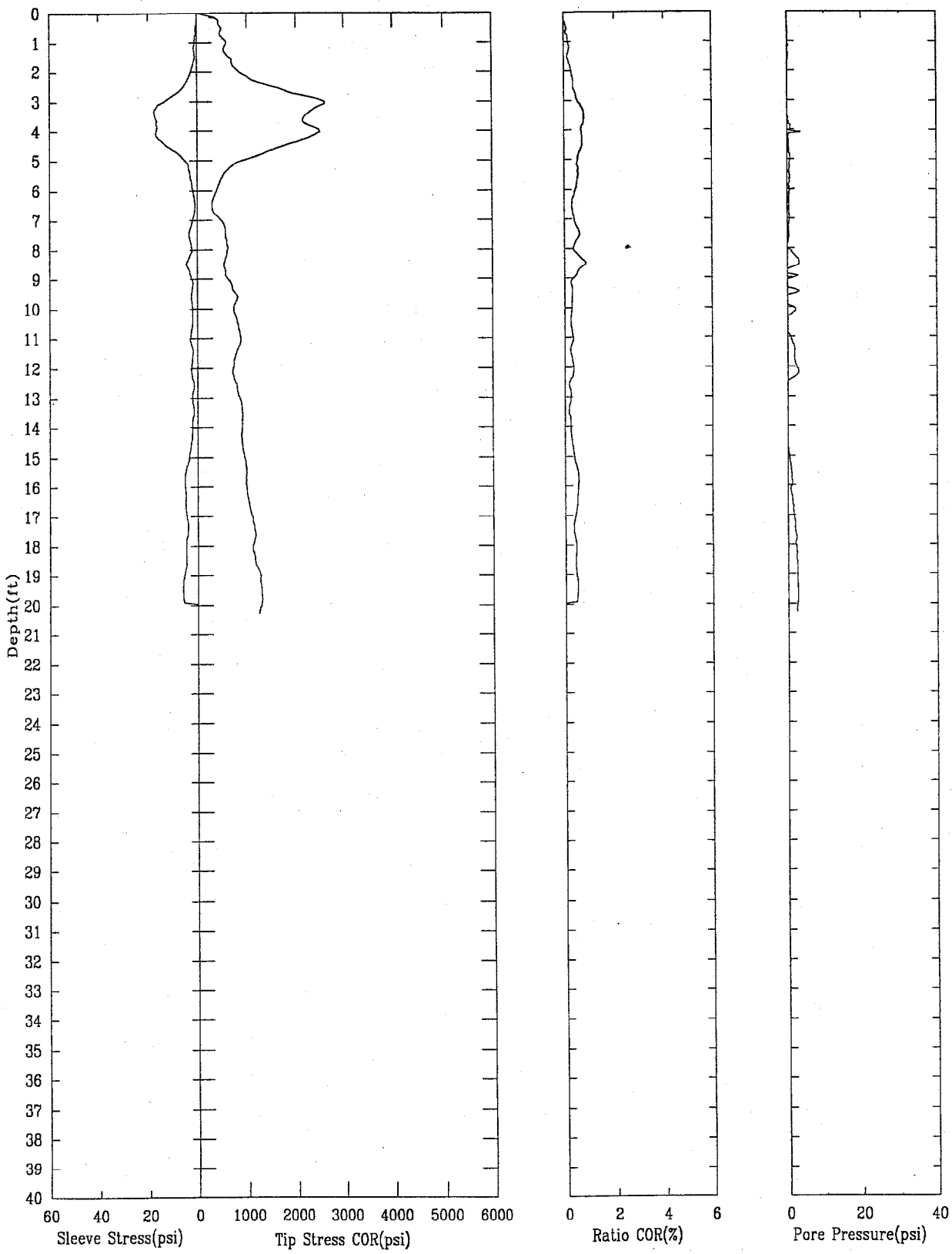


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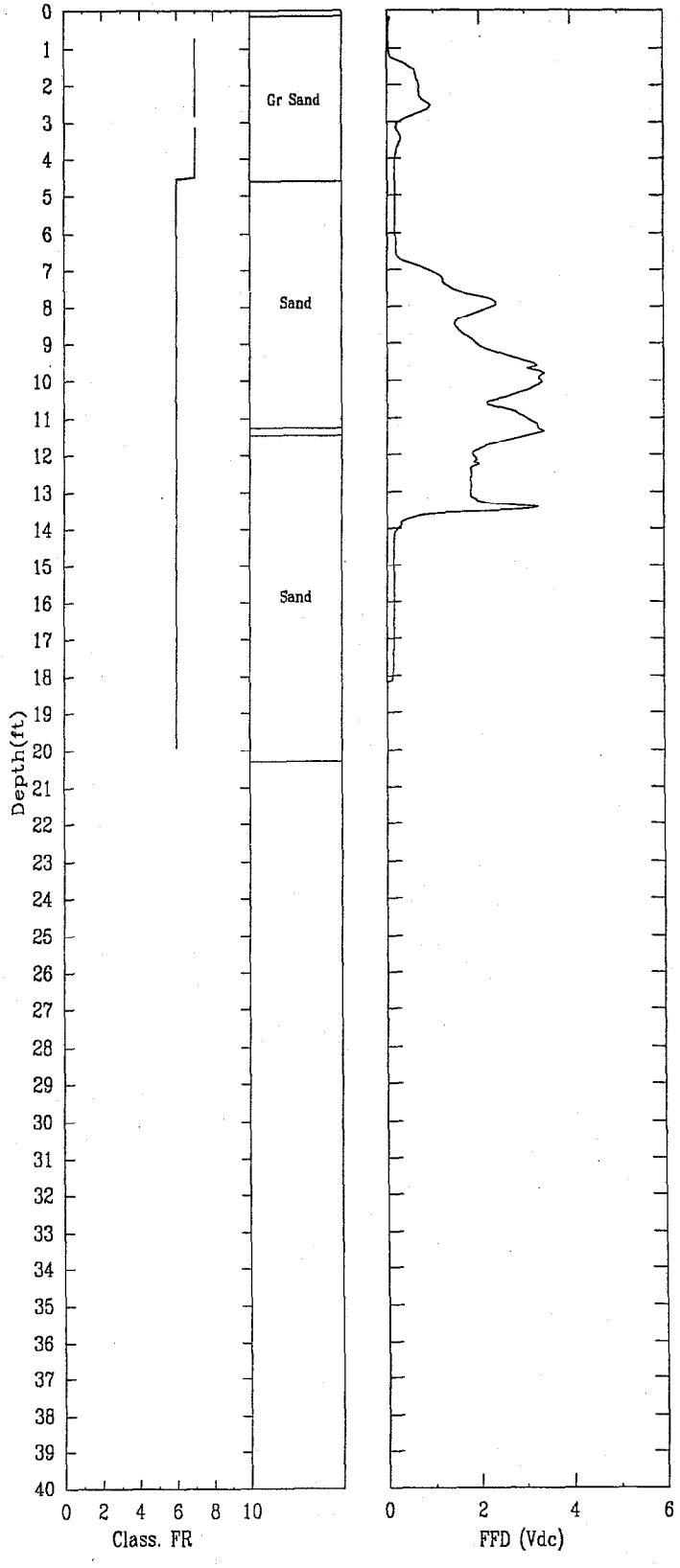


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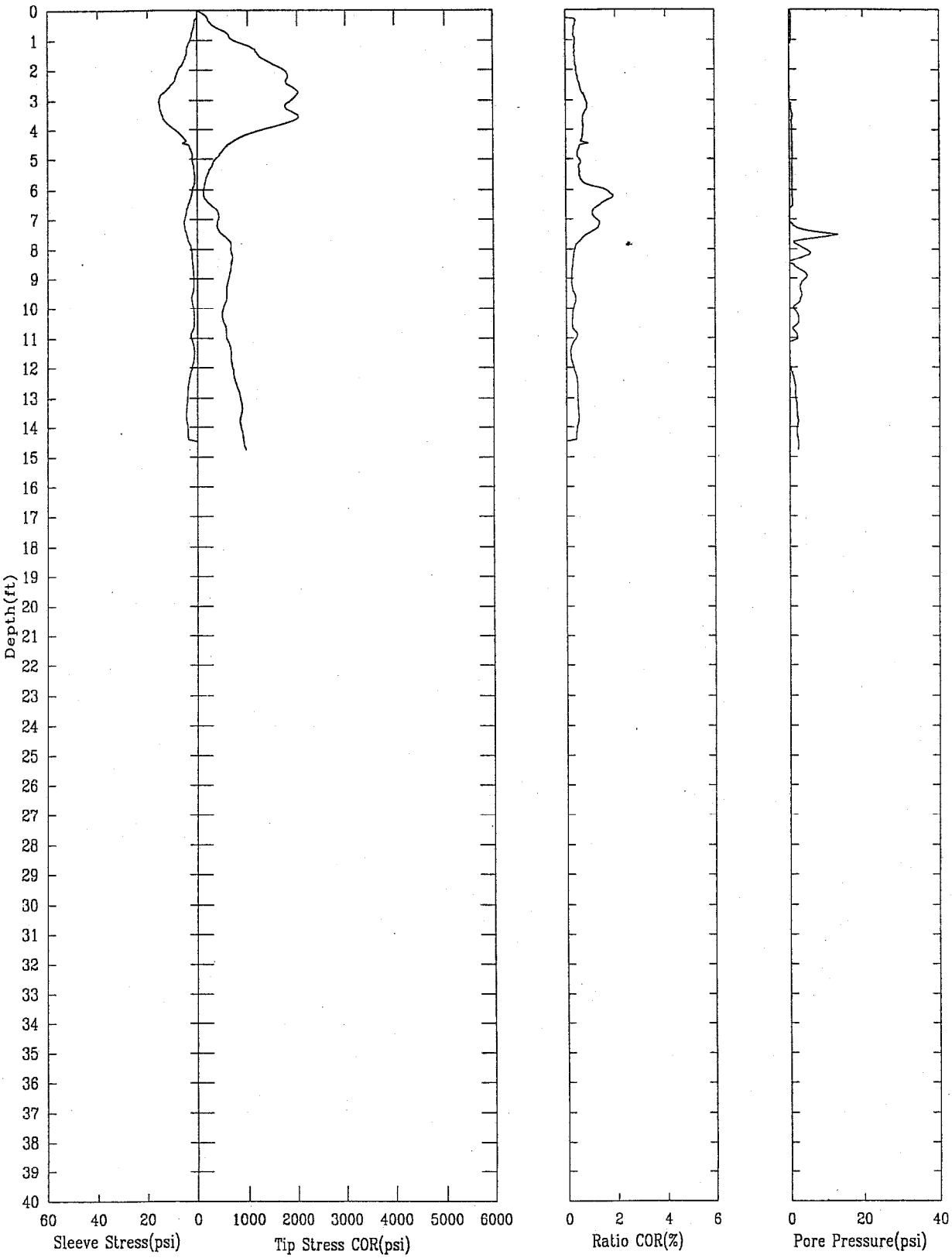


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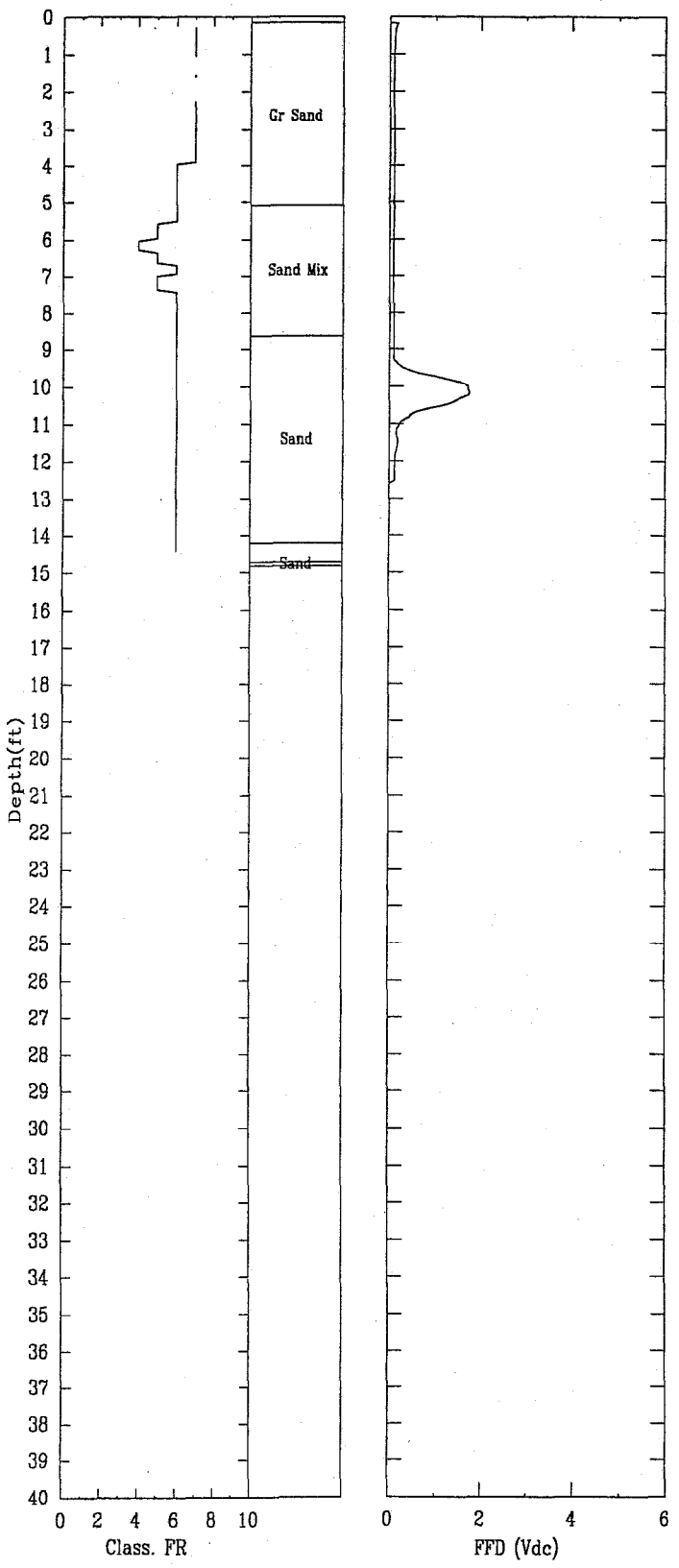


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16CPT-26 APPLIED RESEARCH ASSOCIATES, INC. 10/15/96

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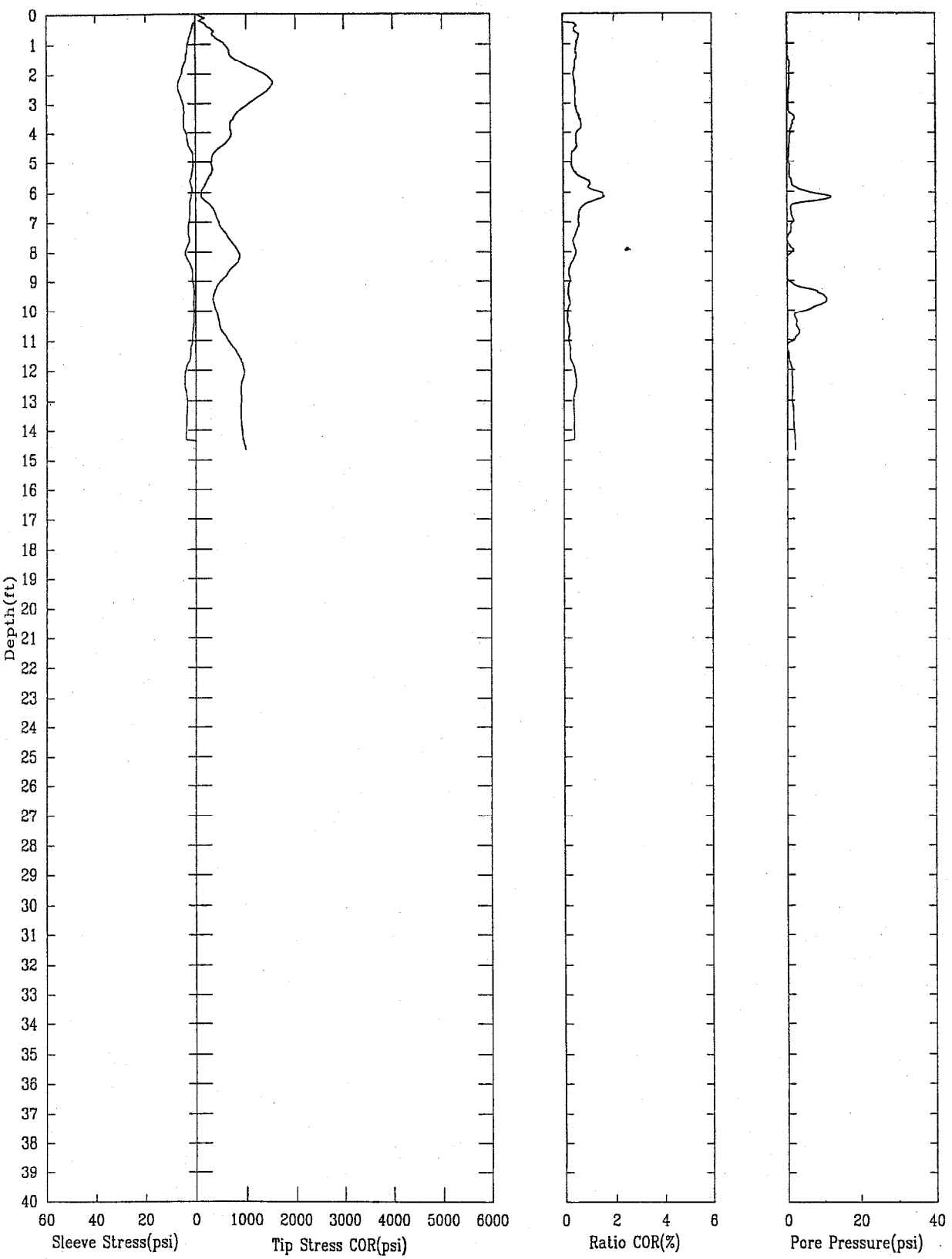


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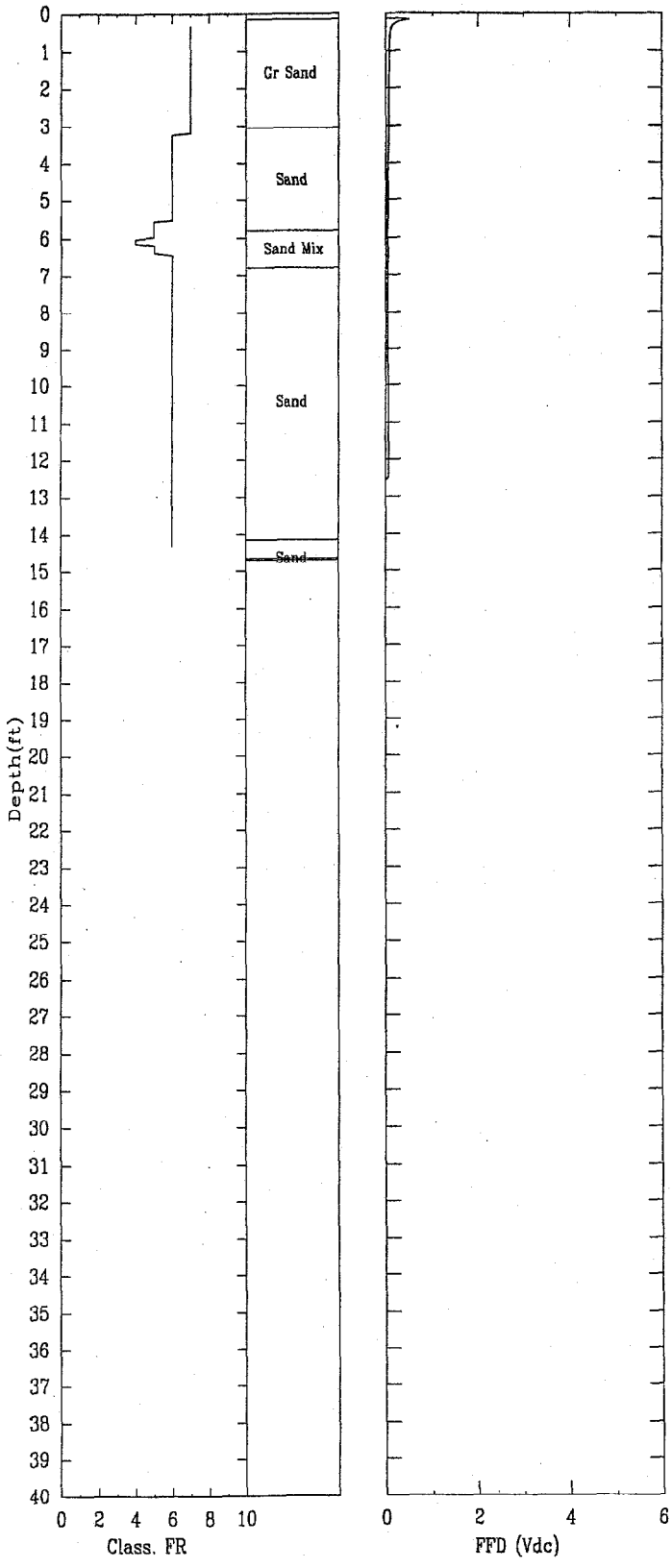


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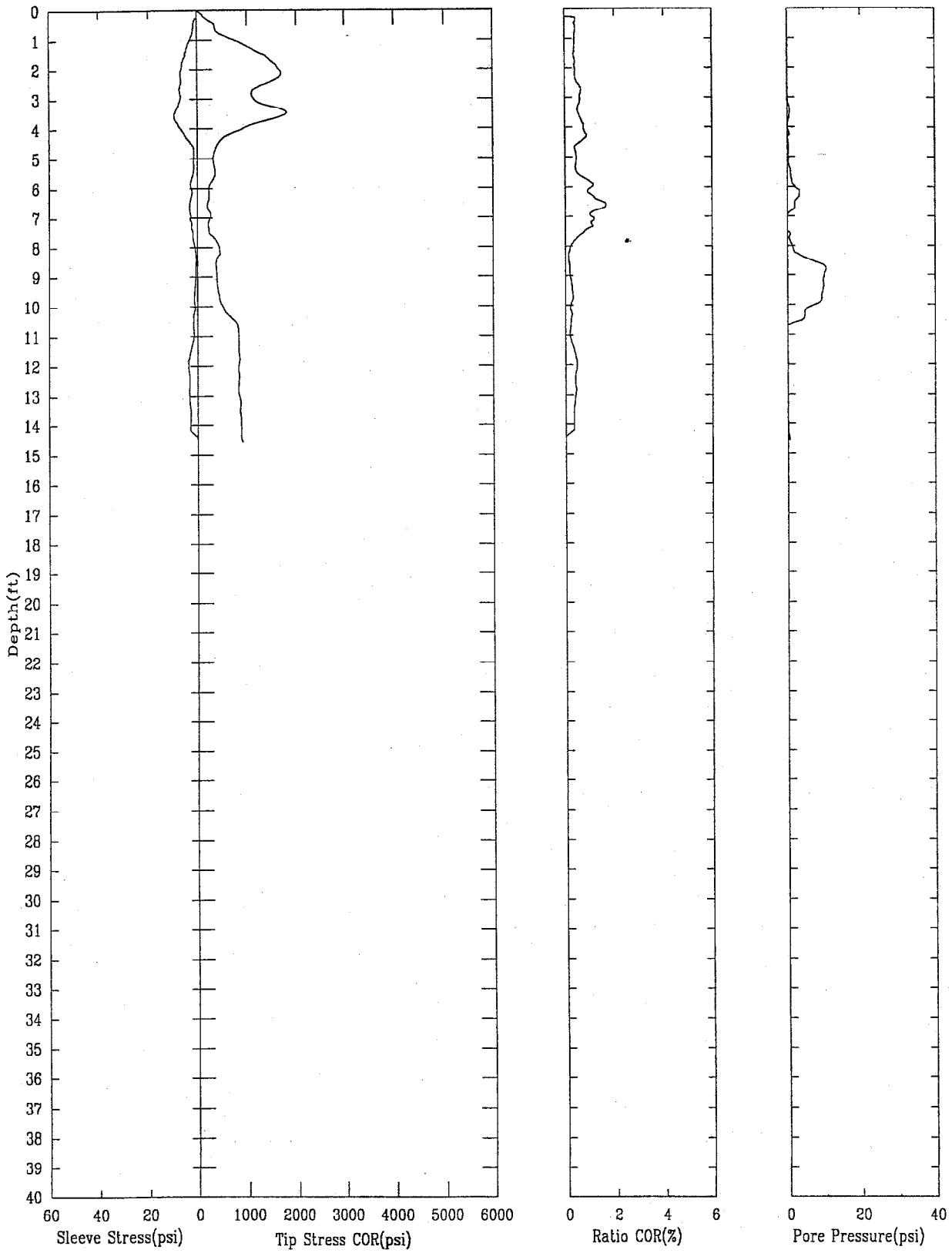


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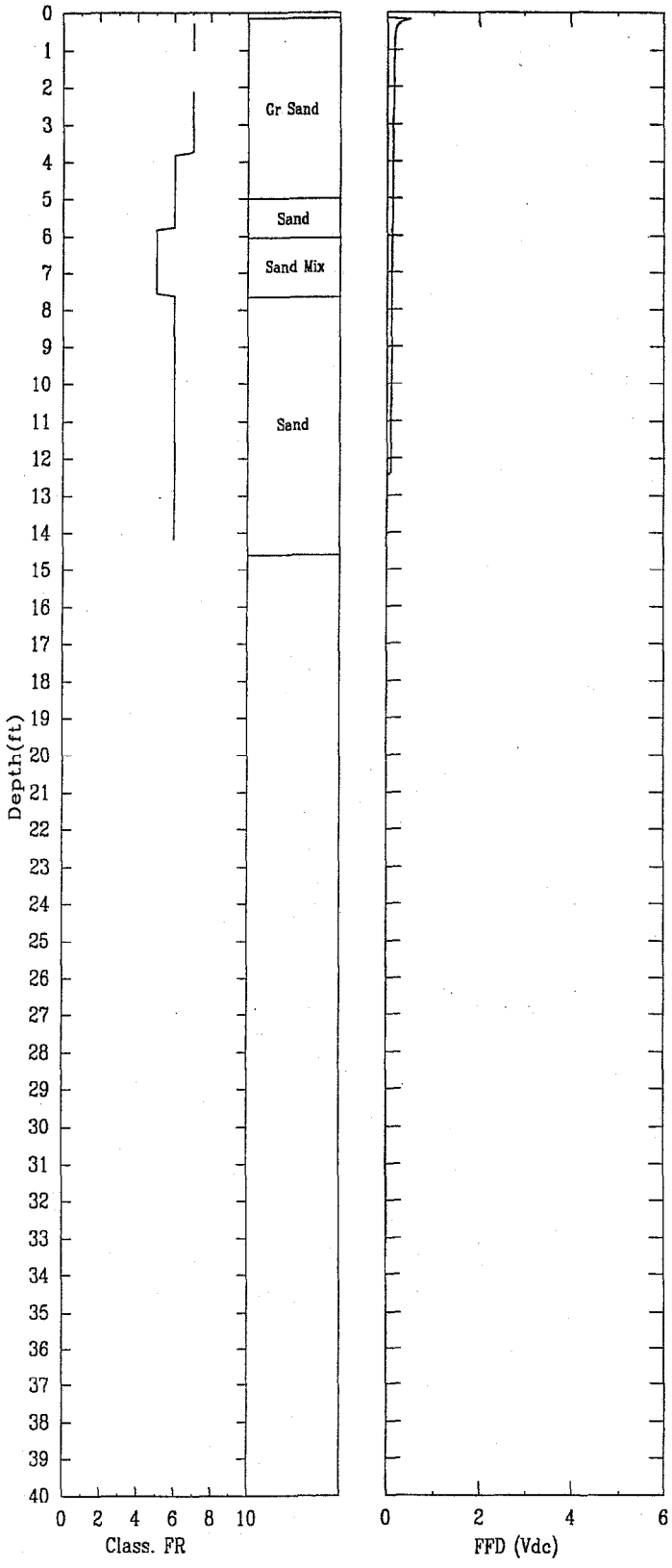


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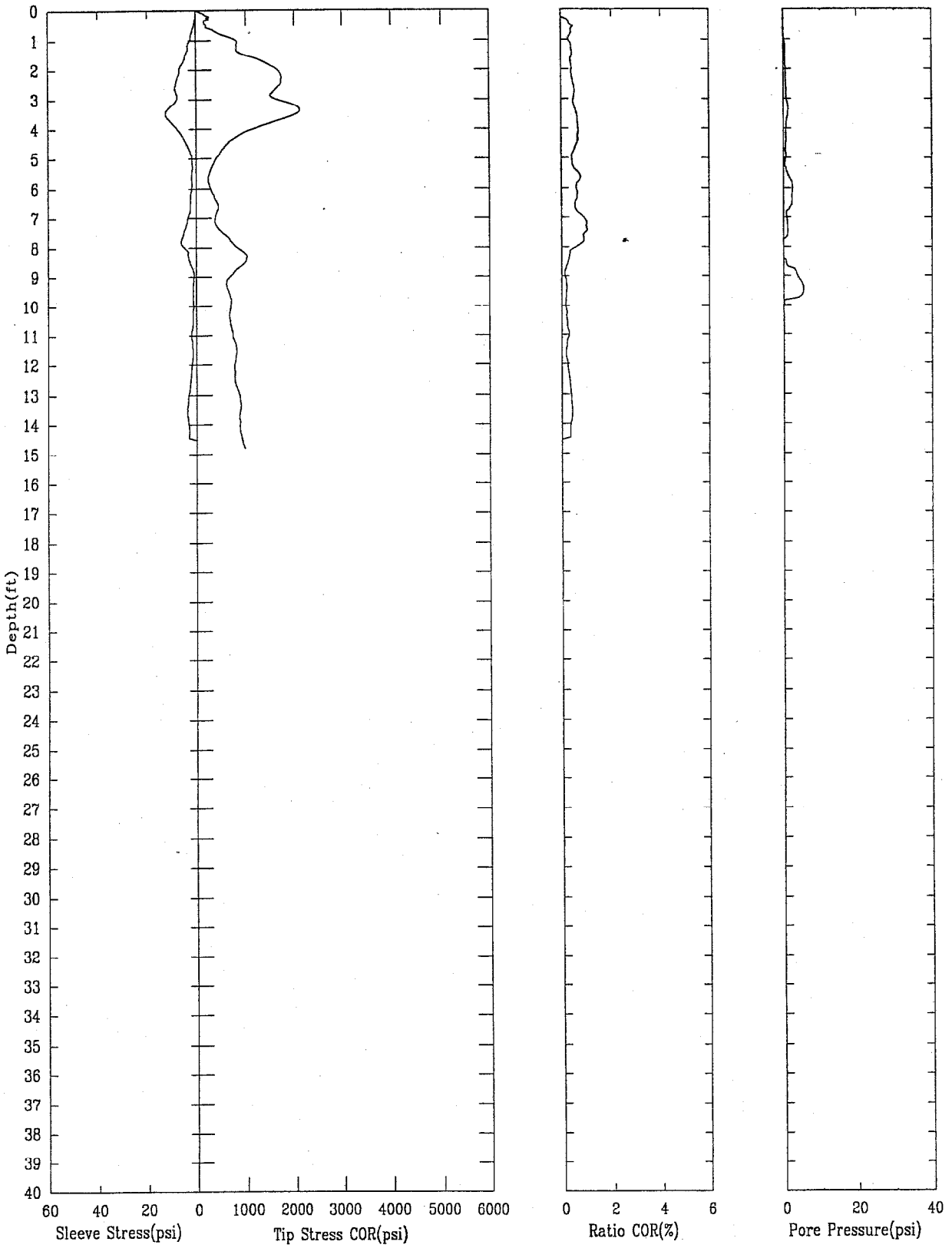


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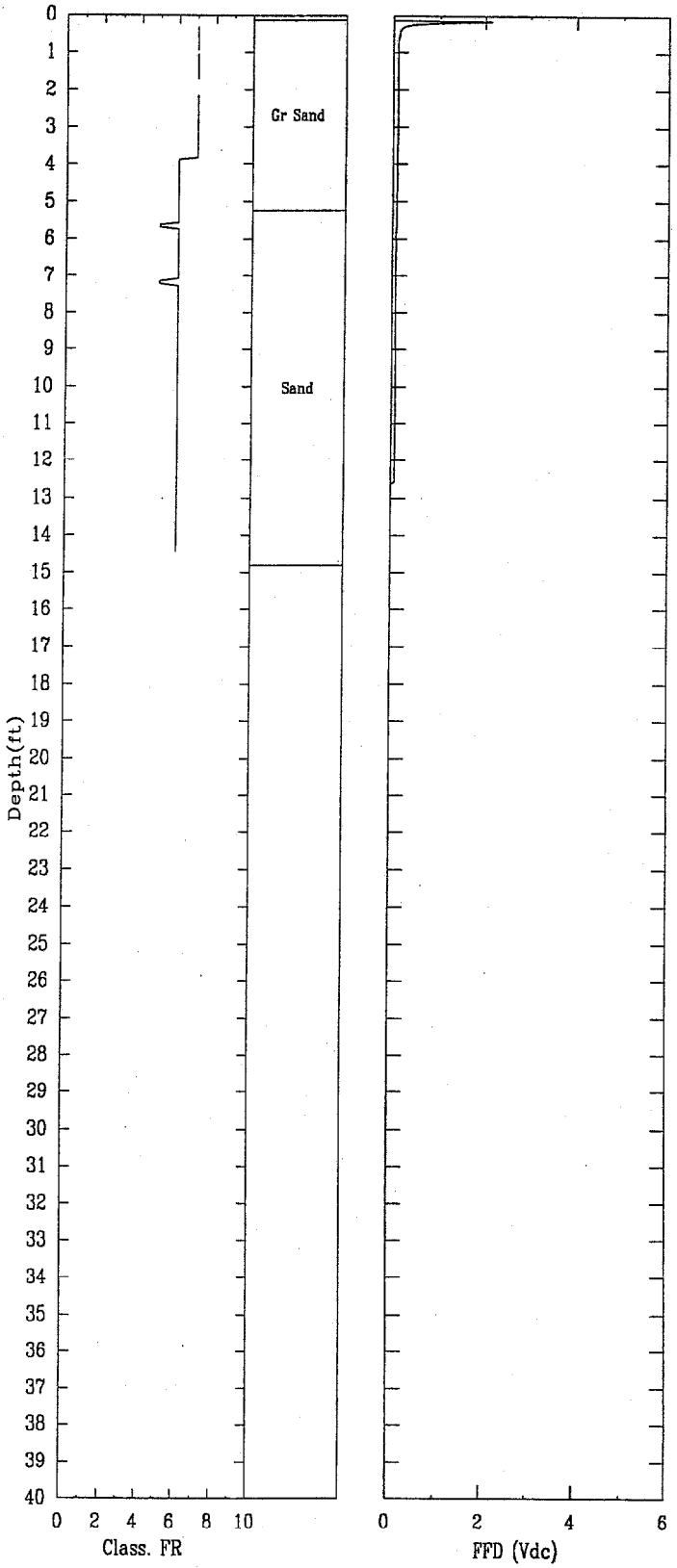


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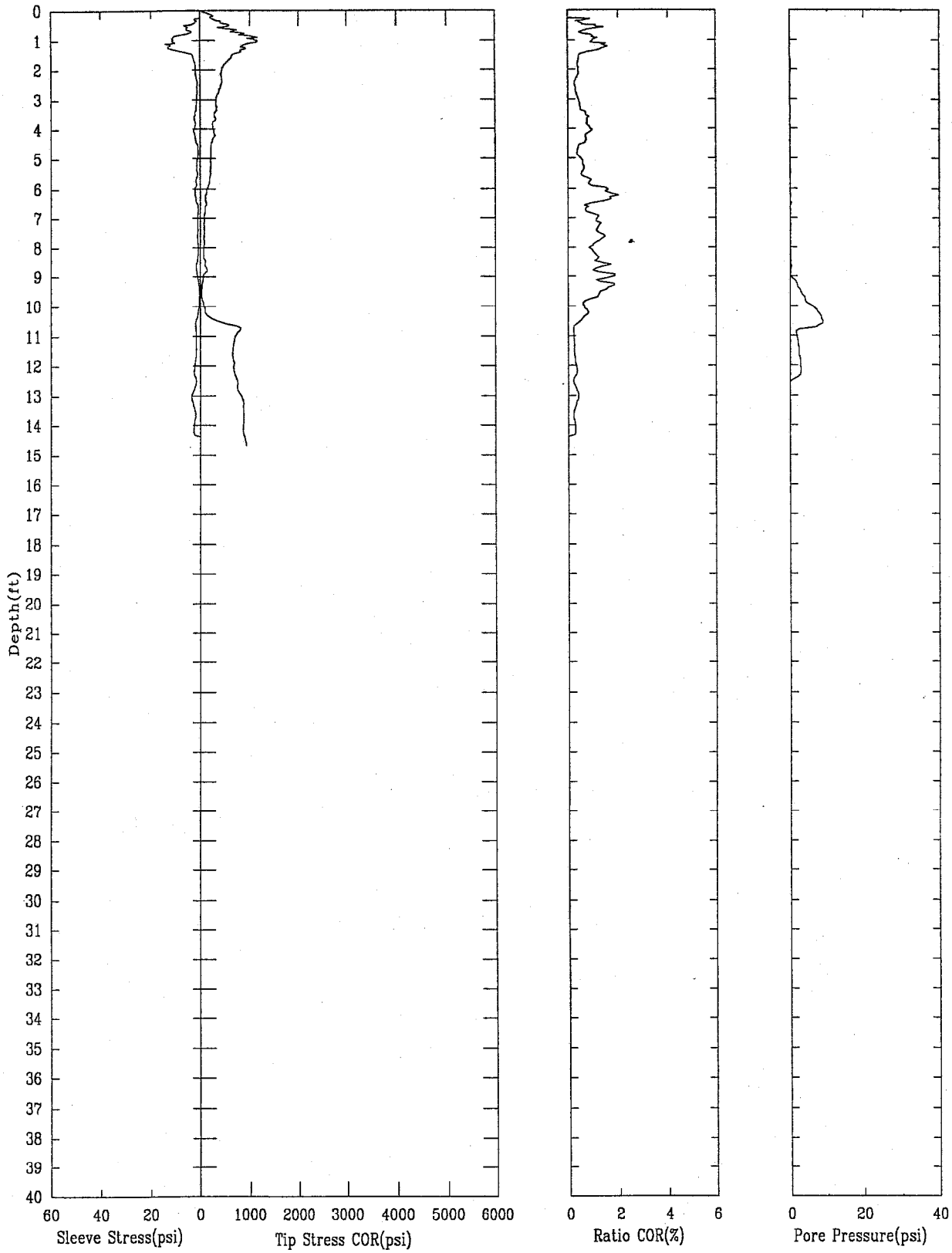


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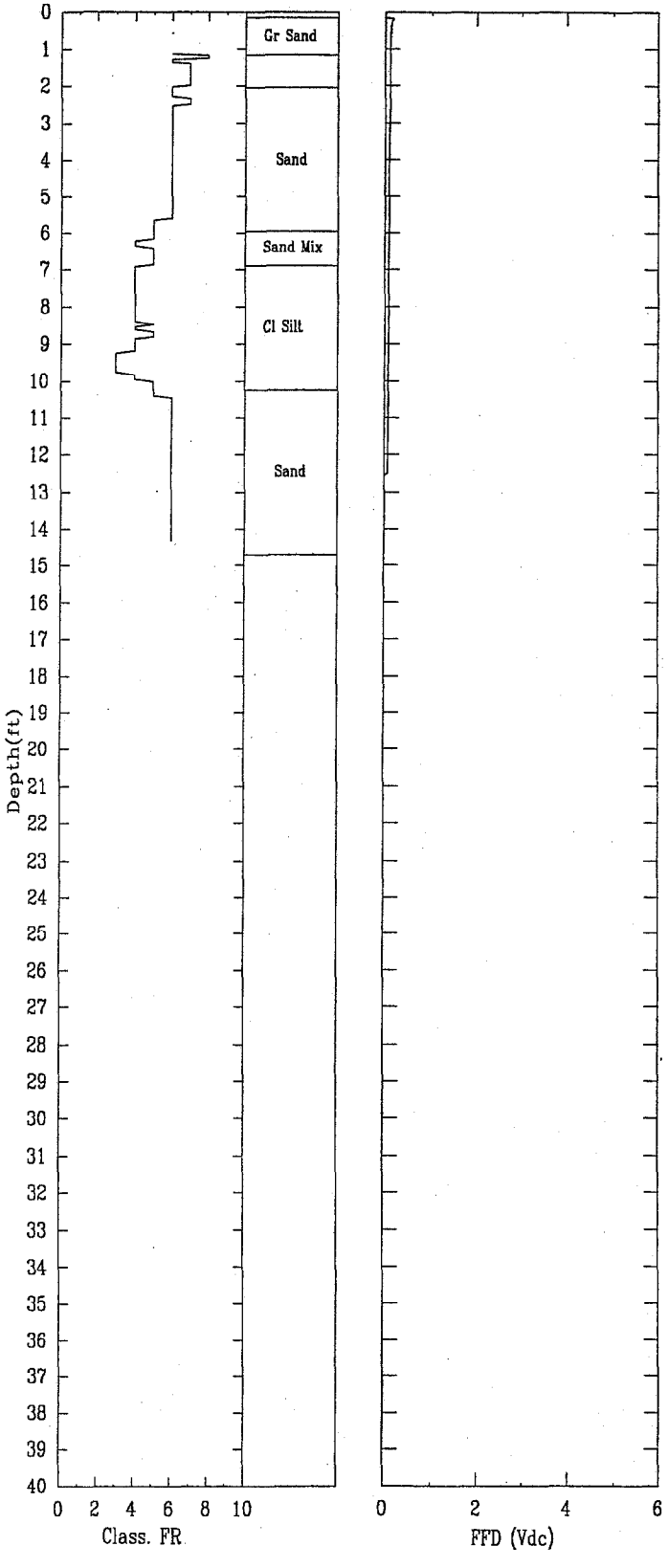


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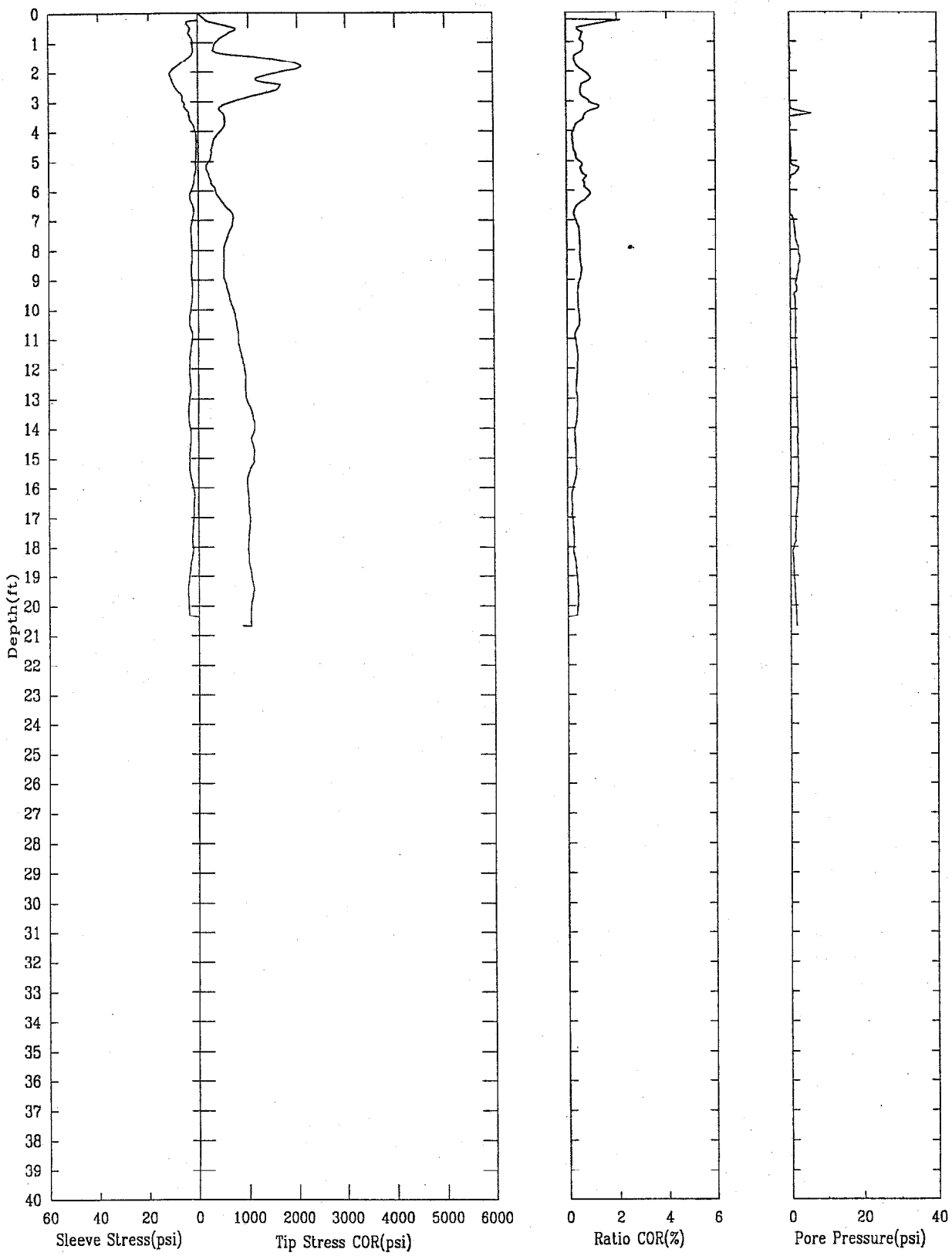


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16CPT-30 APPLIED RESEARCH ASSOCIATES, INC. 10/15/96

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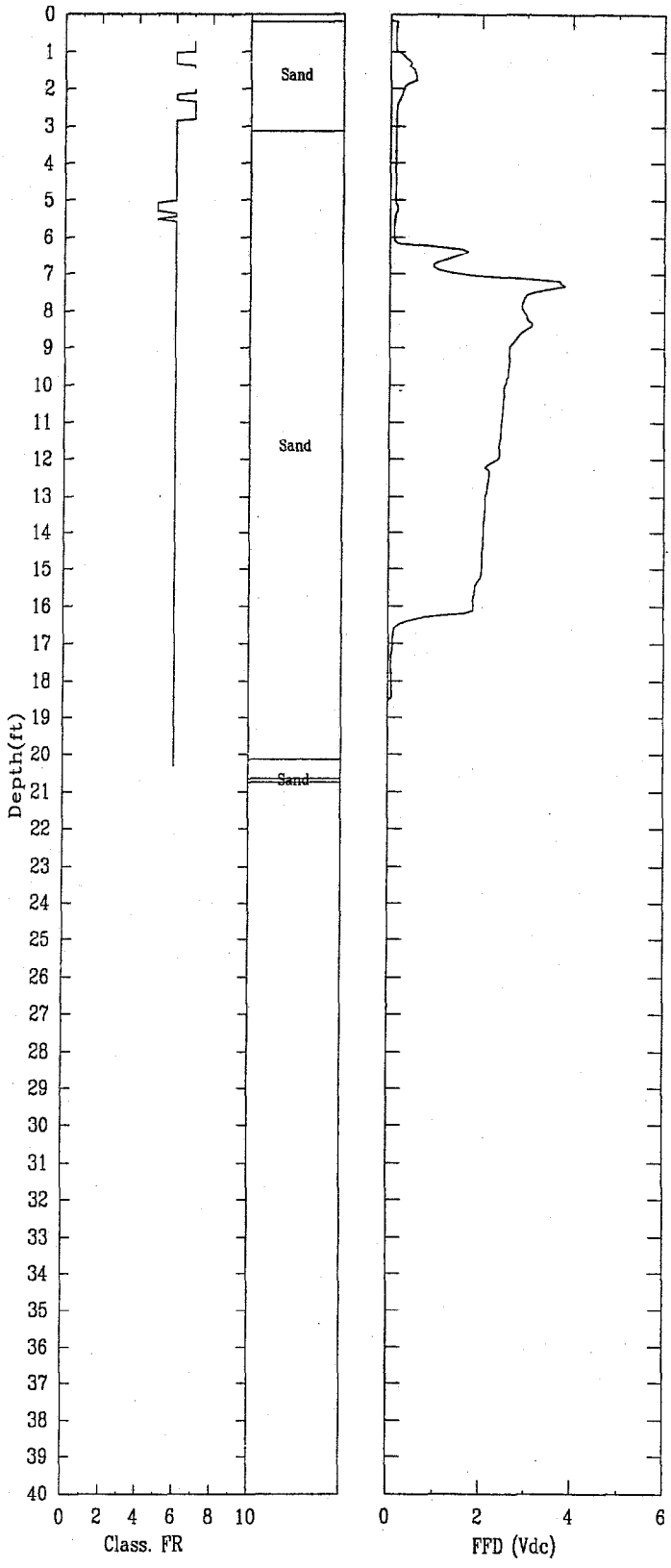


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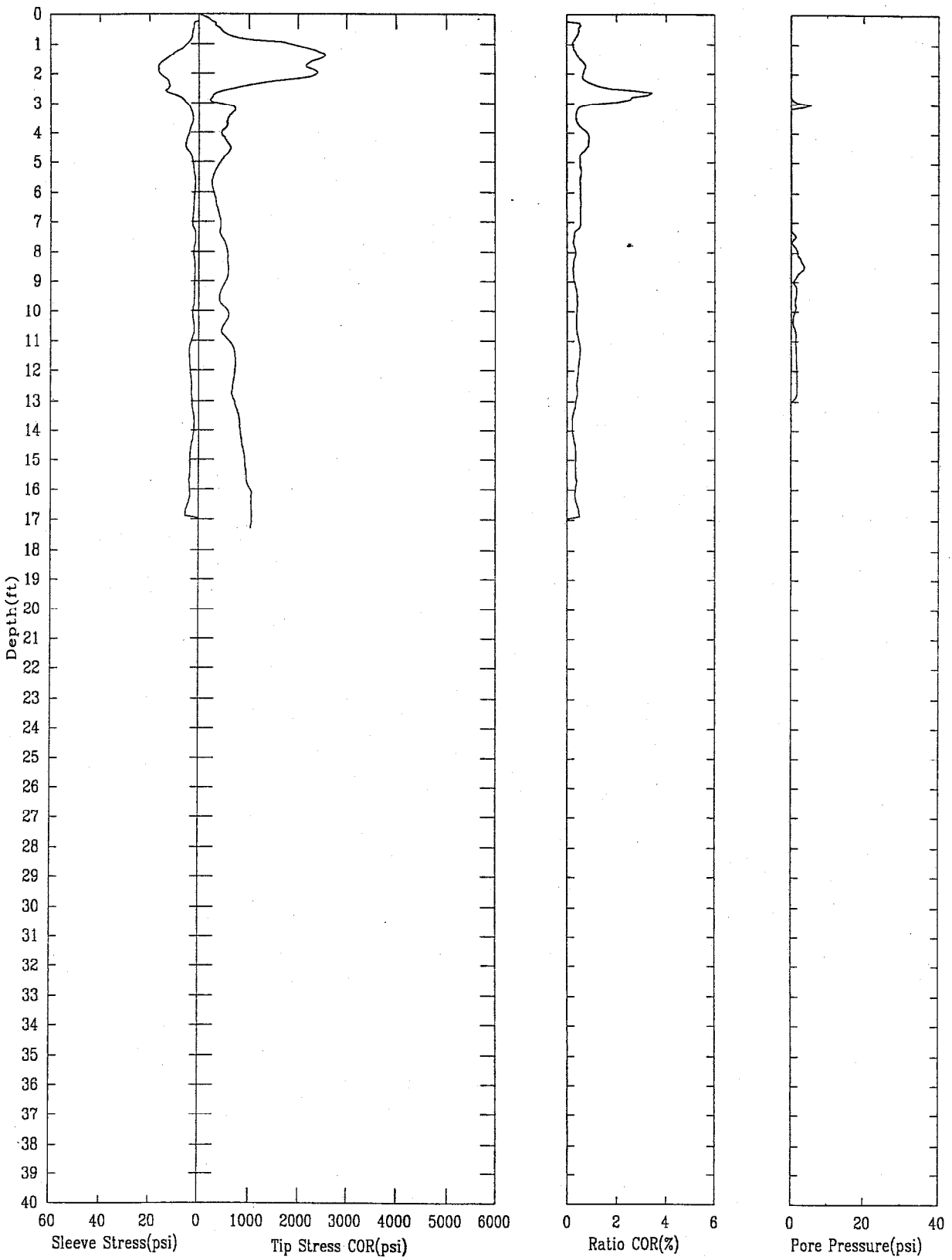


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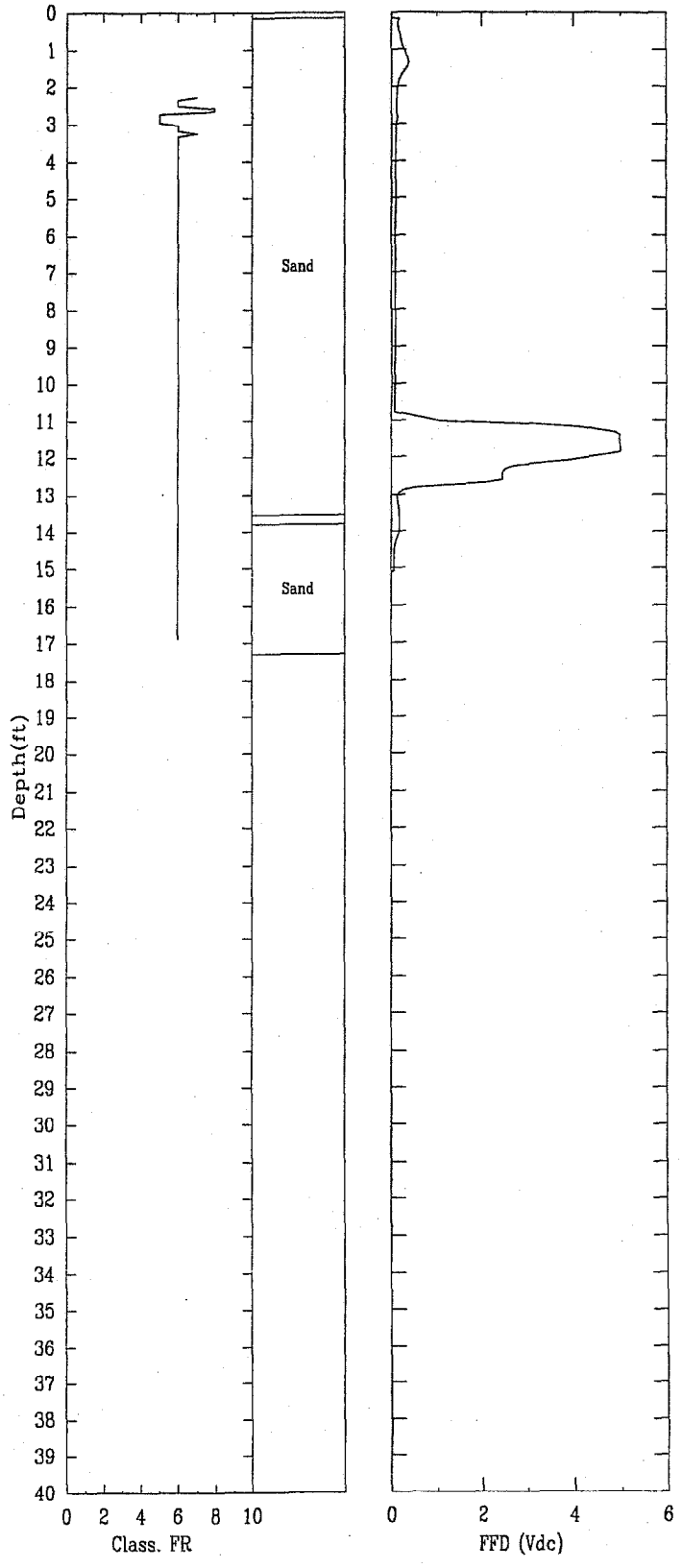


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26CPT-00 APPLIED RESEARCH ASSOCIATES, INC. 10/22/96

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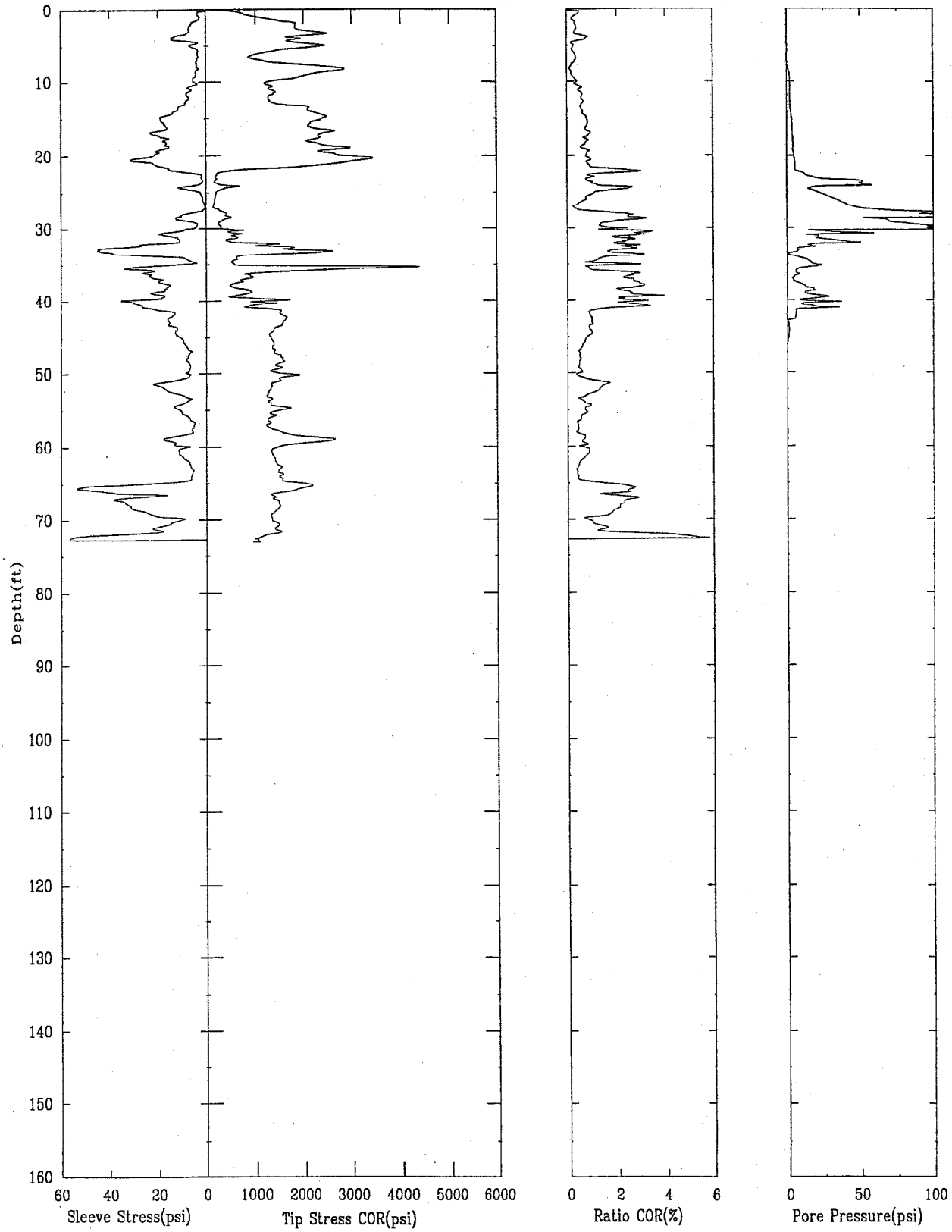


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26CPT-00 APPLIED RESEARCH ASSOCIATES, INC. 10/22/96

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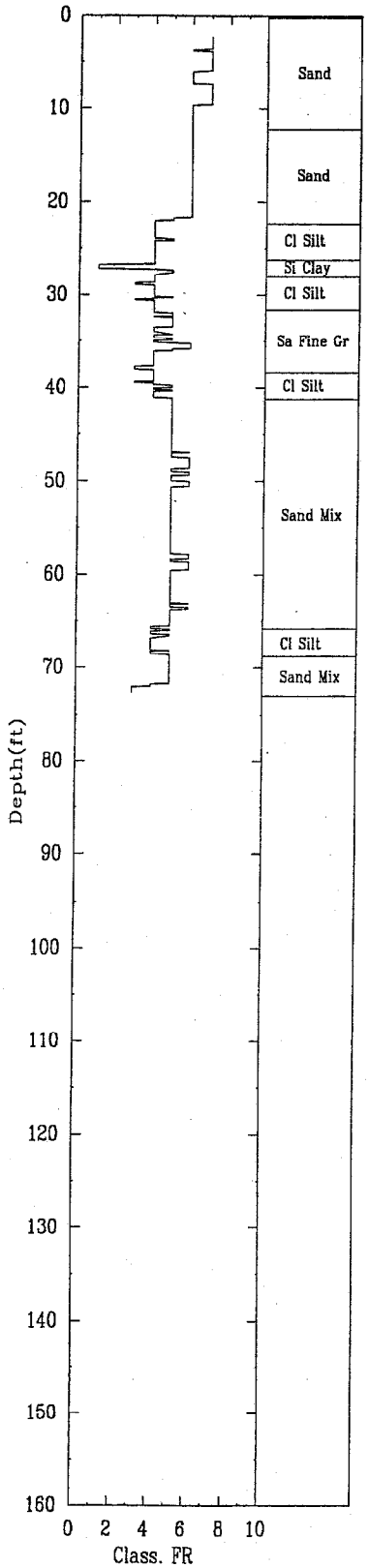


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26HP-01 APPLIED RESEARCH ASSOCIATES, INC. 10/16/96

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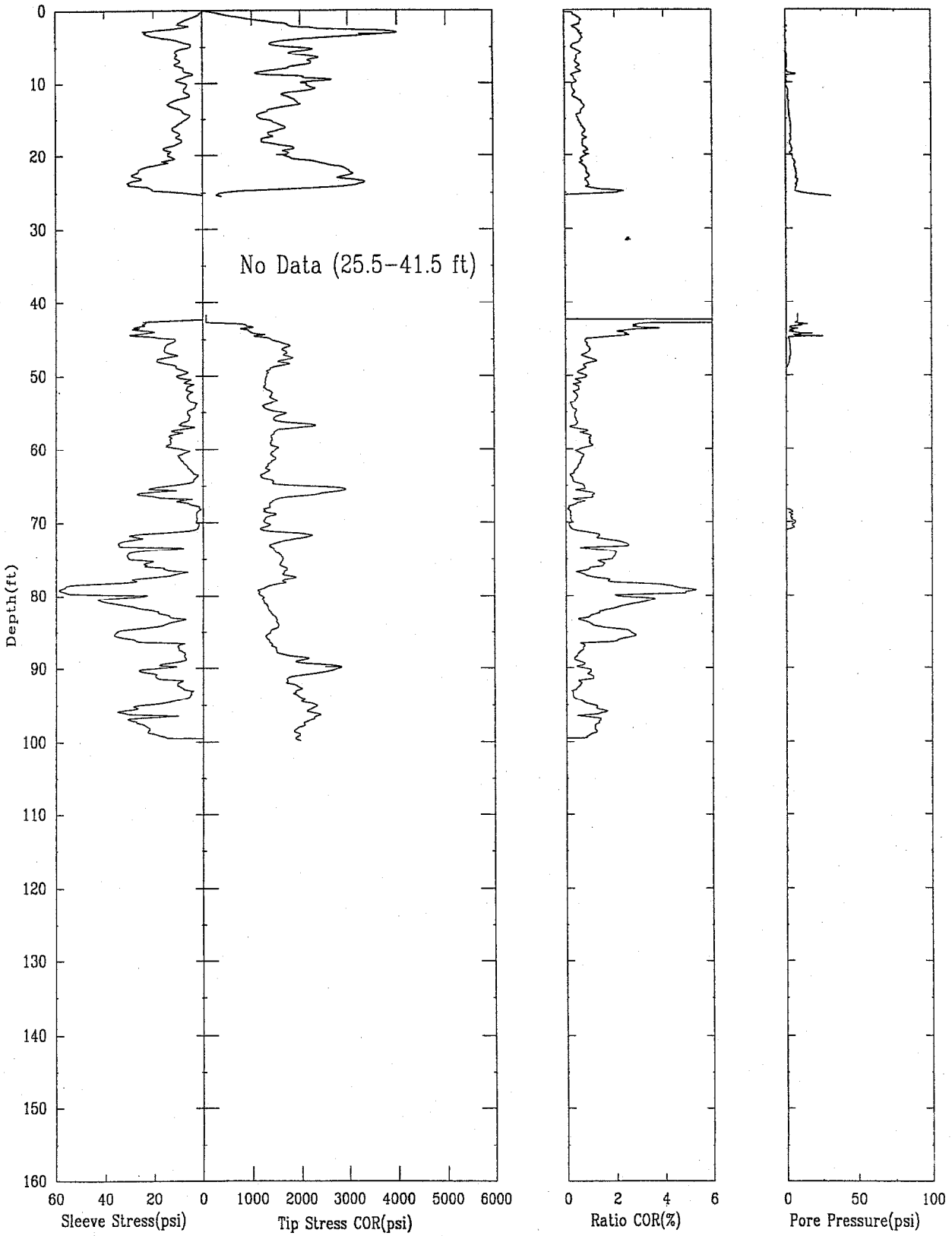


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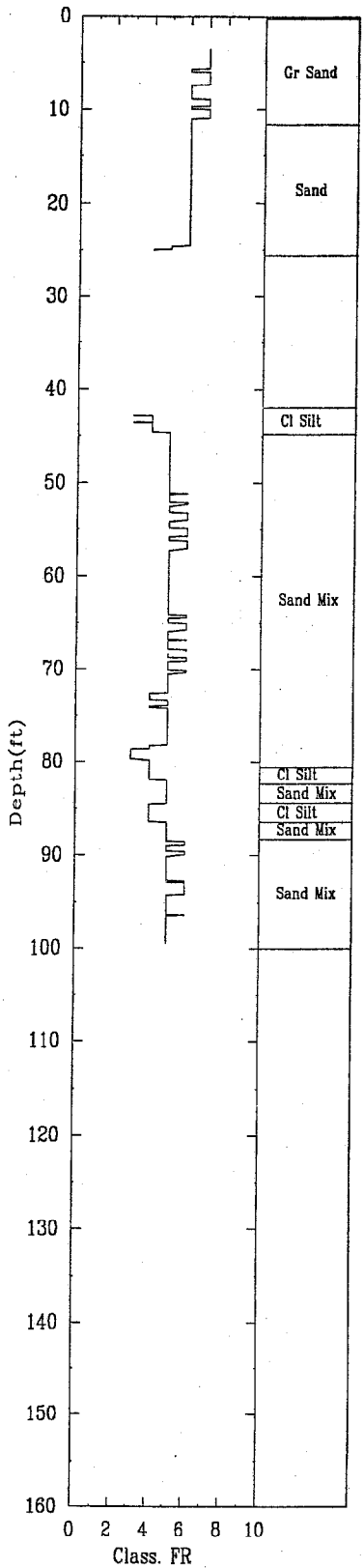


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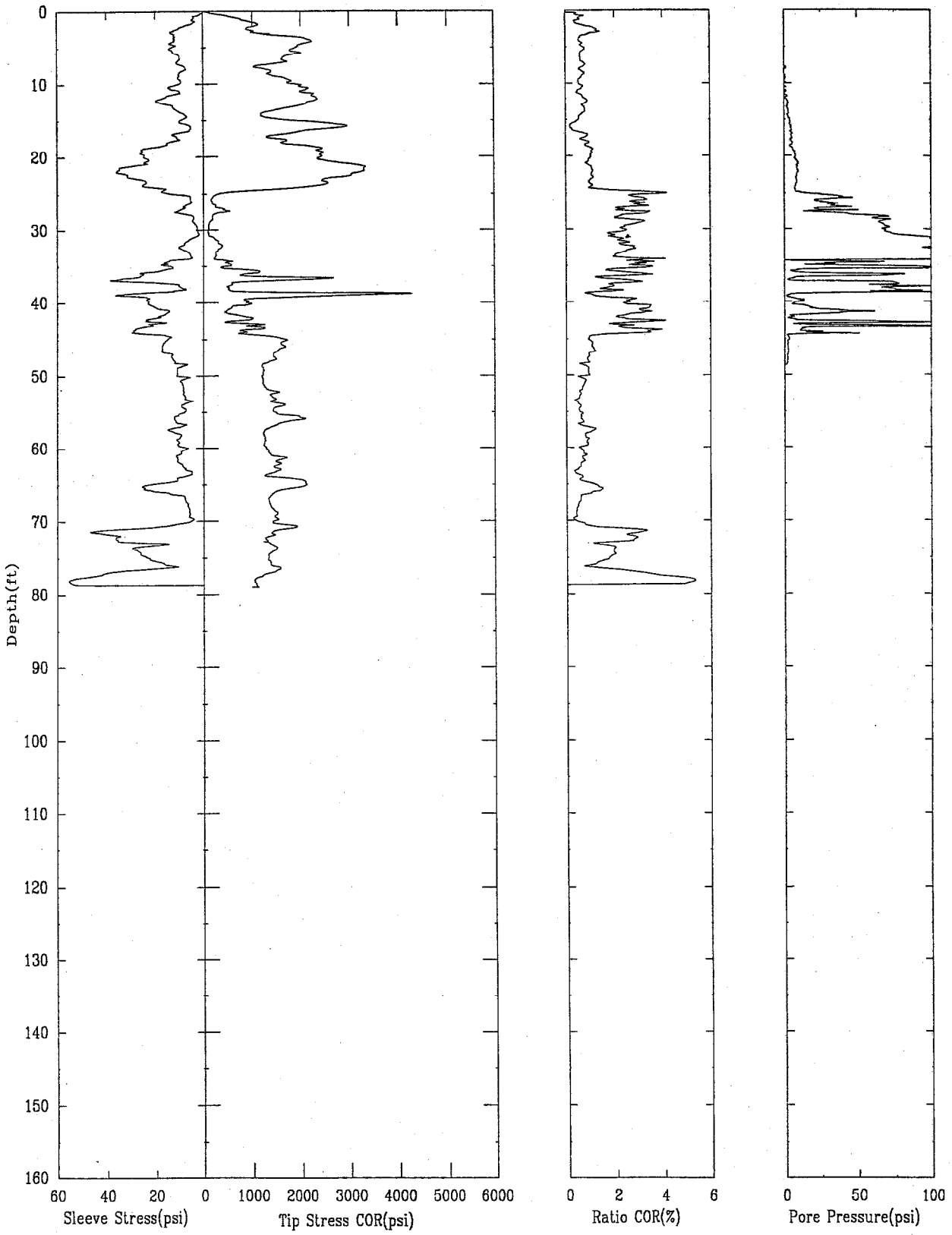


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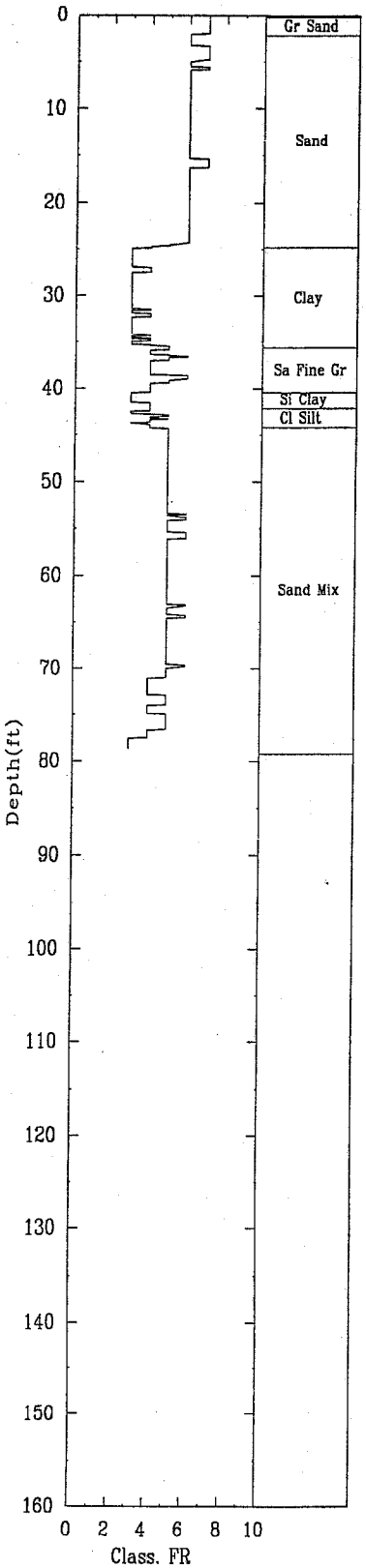


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26HP-05 APPLIED RESEARCH ASSOCIATES, INC. 10/22/96

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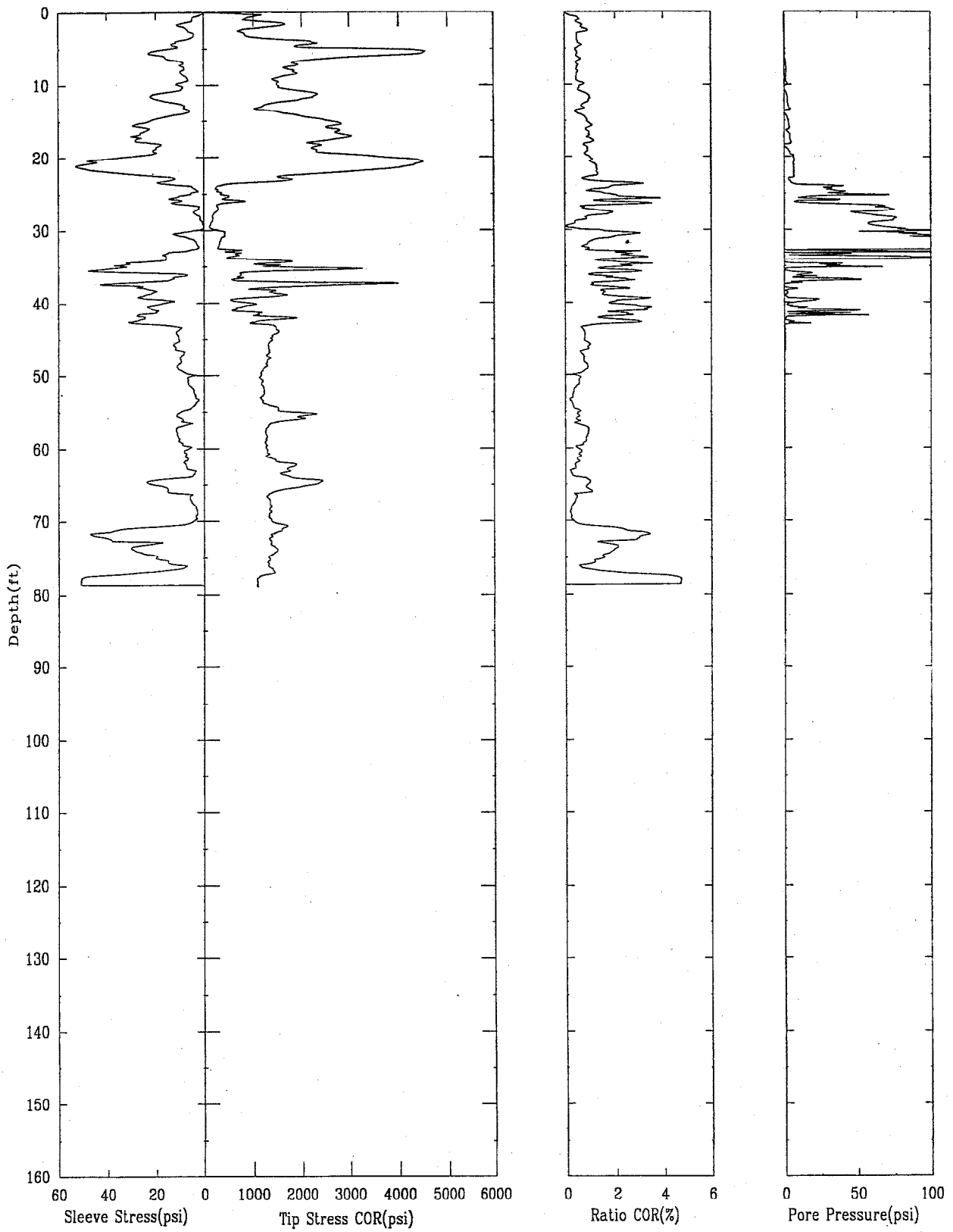


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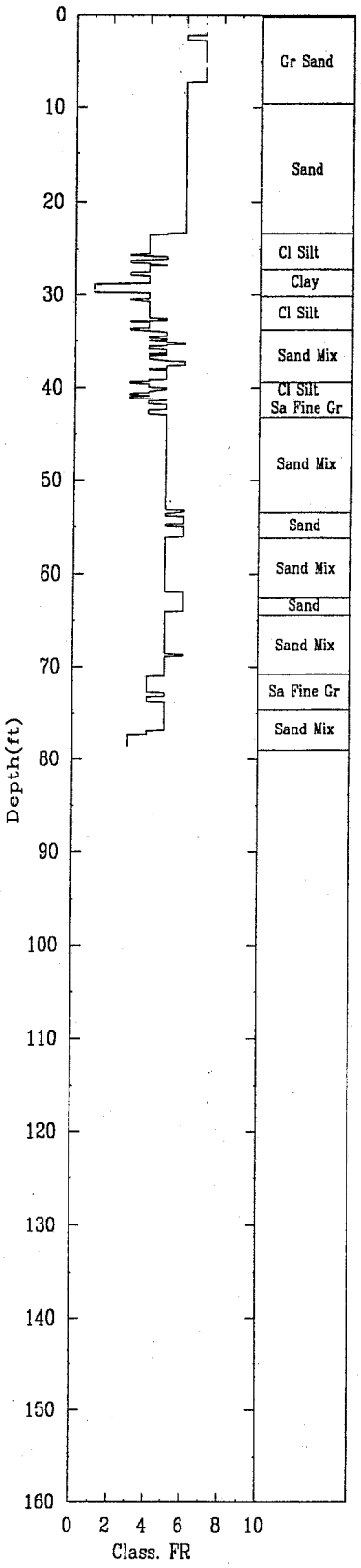


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26HP-08 APPLIED RESEARCH ASSOCIATES, INC. 10/22/96

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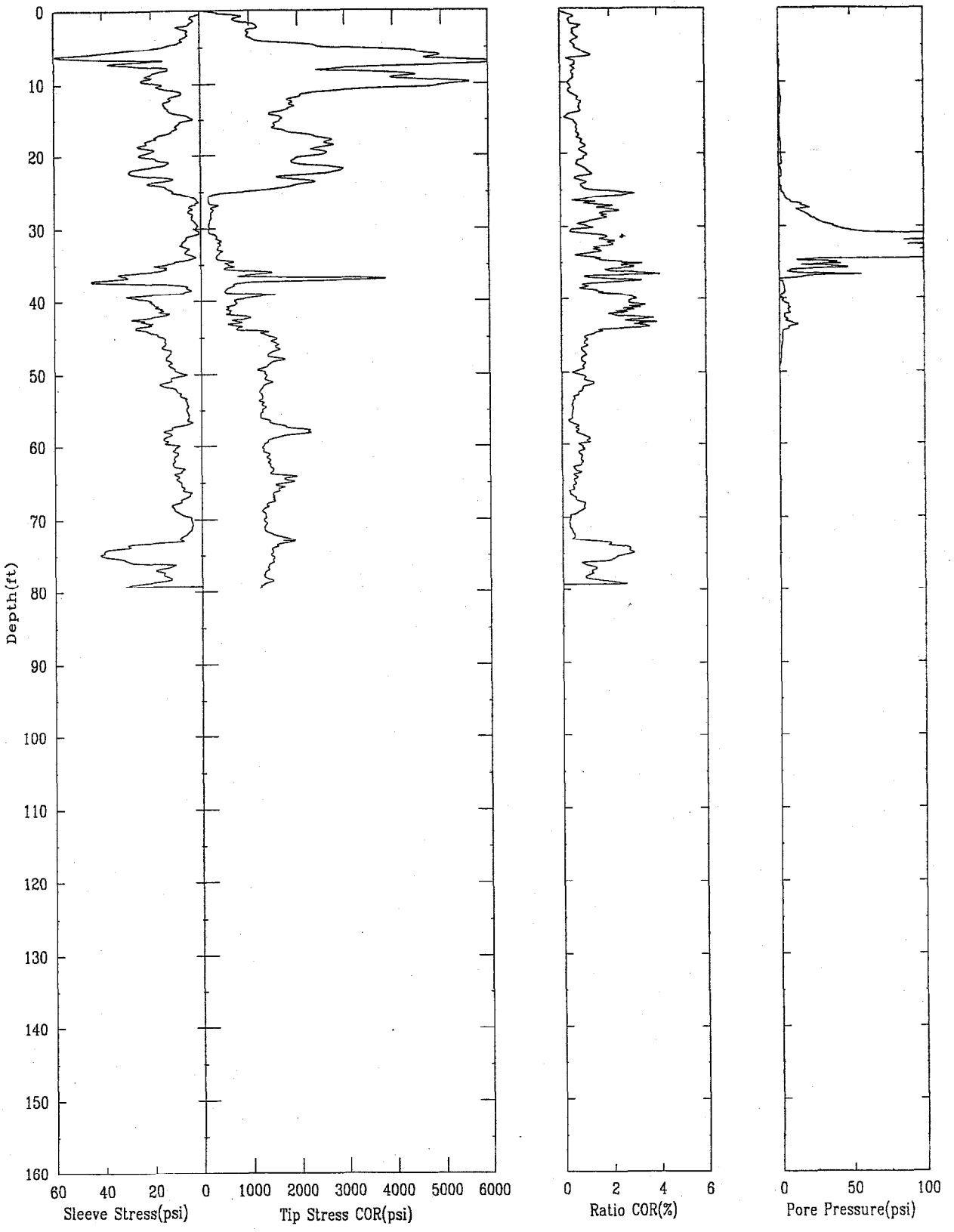


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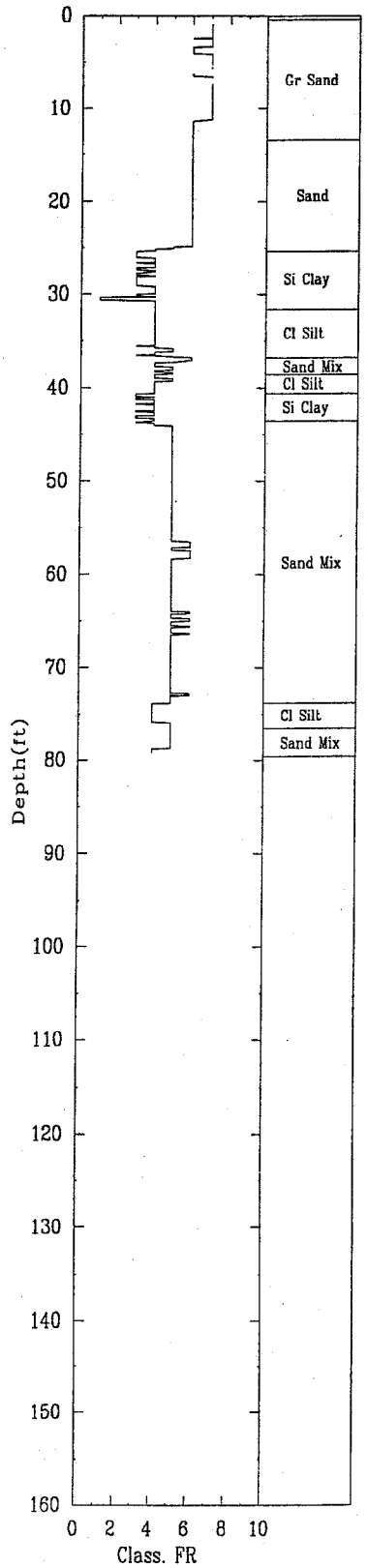


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26HP-10 APPLIED RESEARCH ASSOCIATES, INC. 10/23/96

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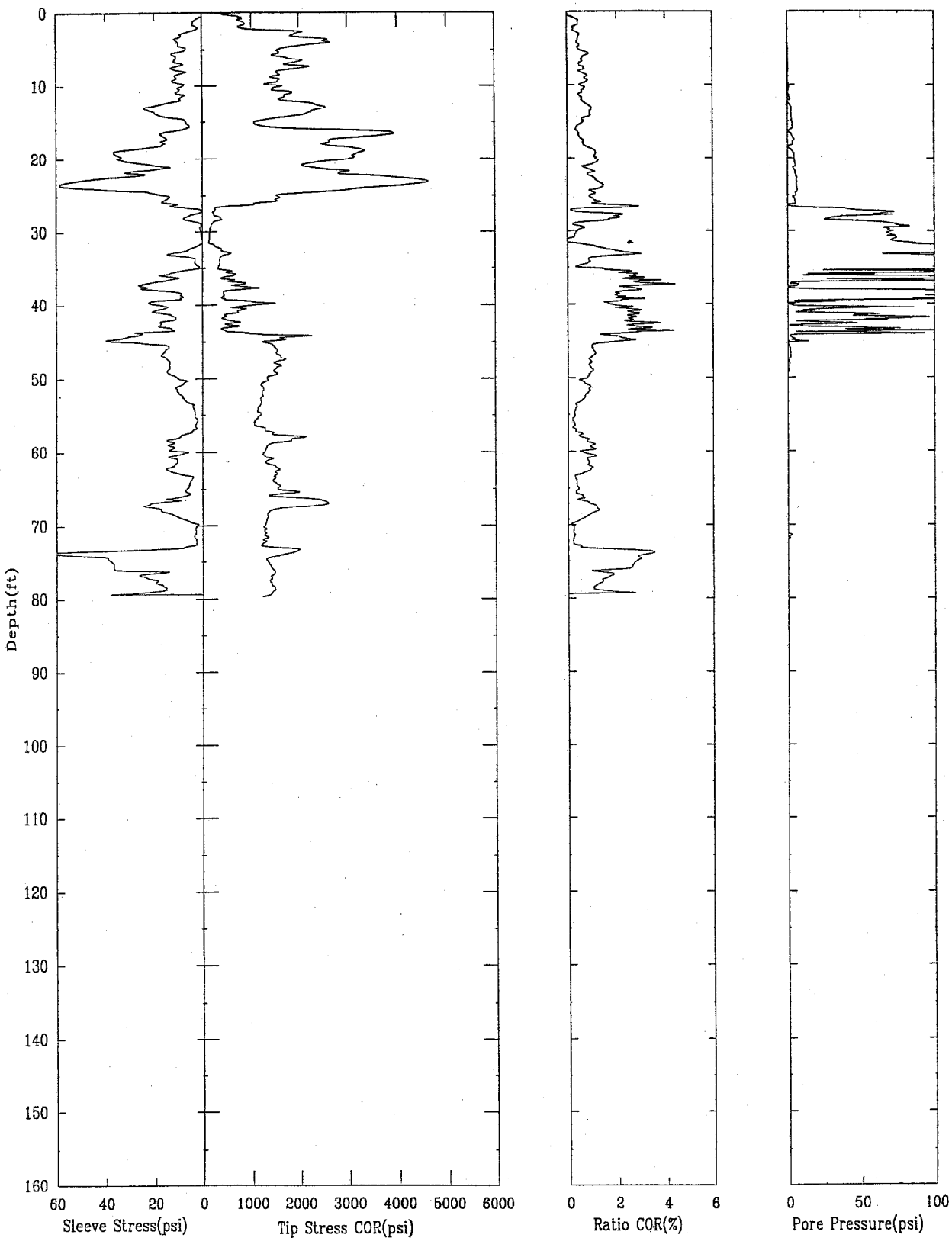


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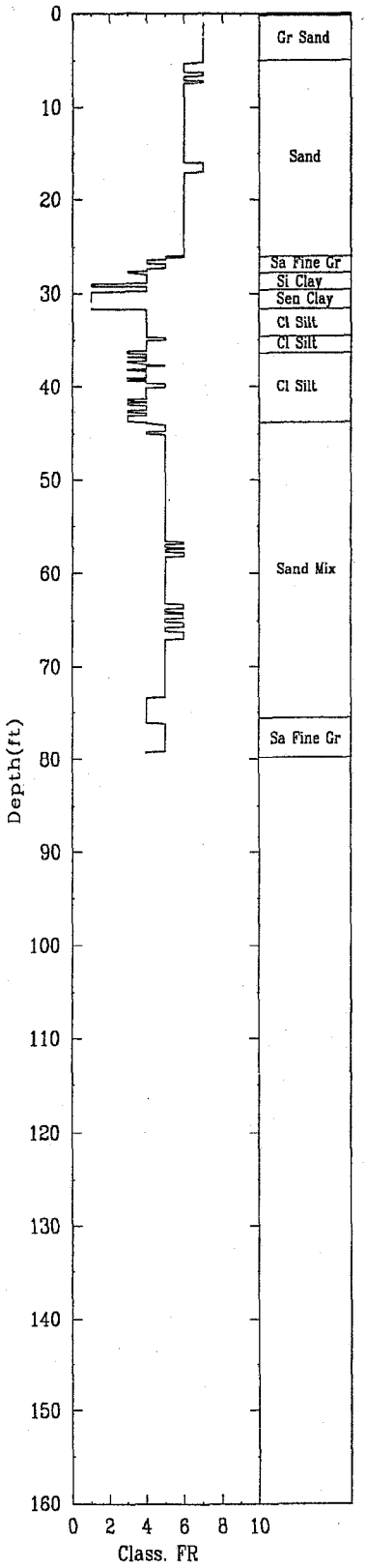


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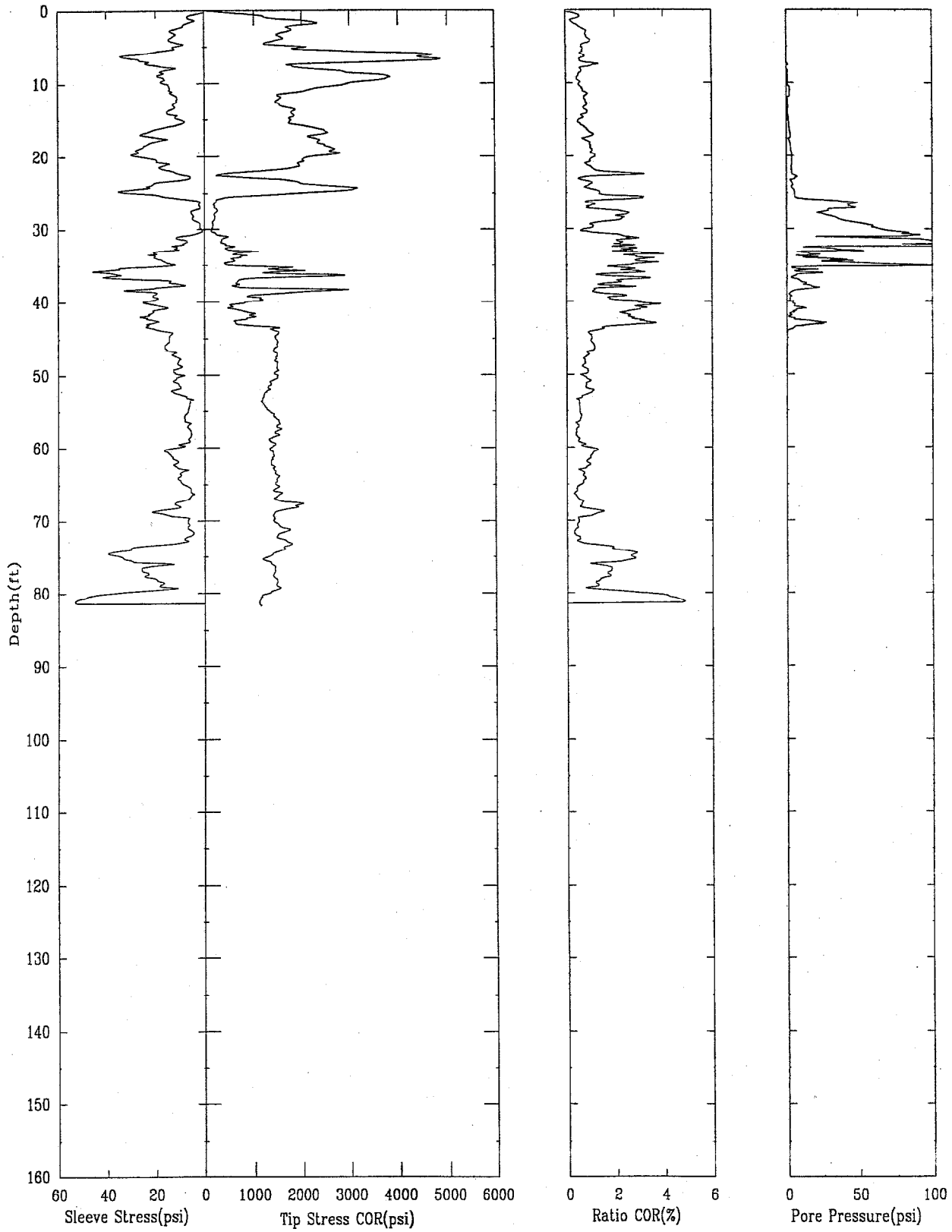


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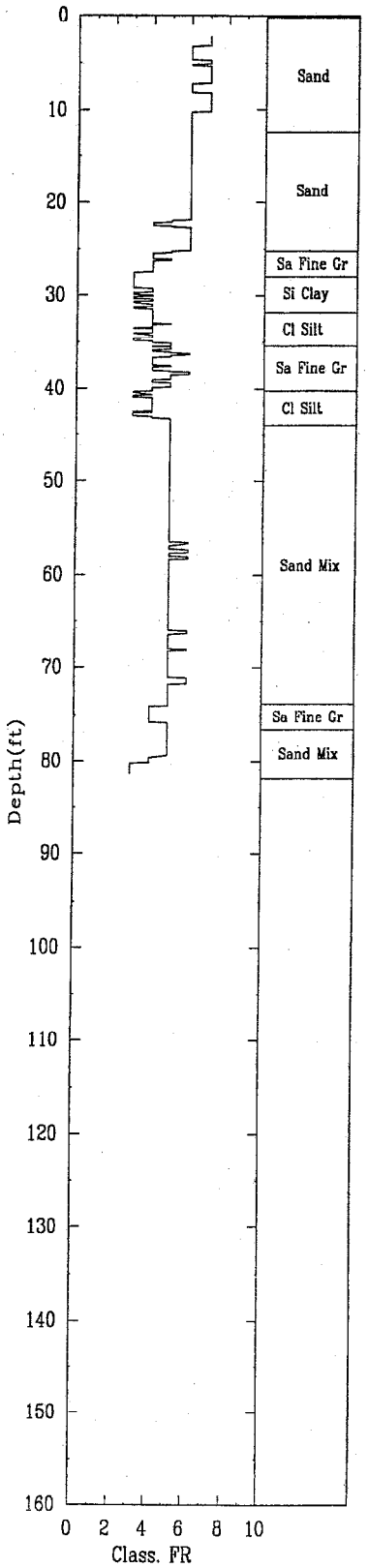


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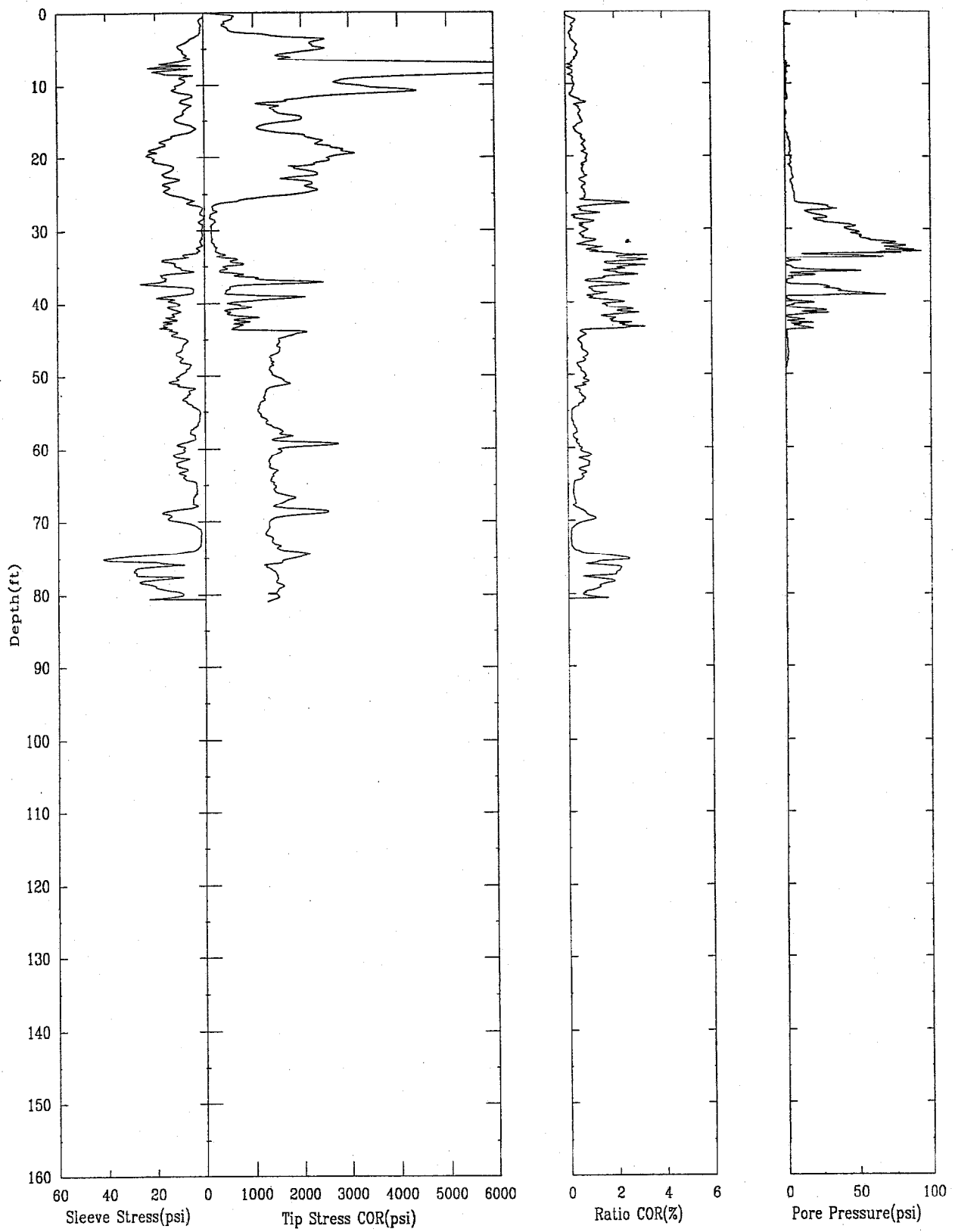


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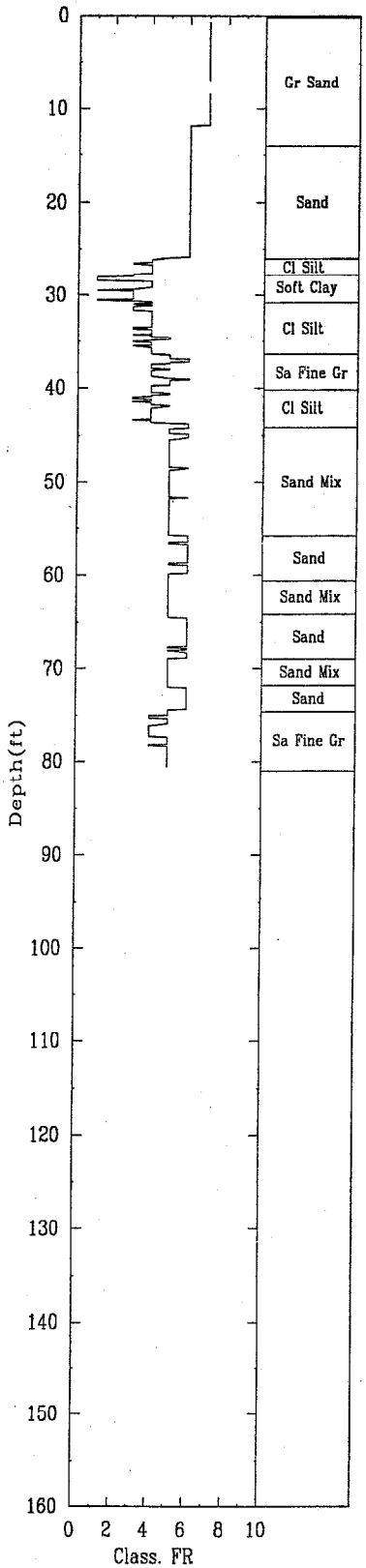


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